TR-224

TECHNICAL REPORT

BIOLOGICAL SOUND SCATTERING STUDIES
PART I
INITIAL INVESTIGATIONS IN THE GULF OF MEXICO AND WESTERN NORTH ATLANTIC

MAY 1970

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ABSTRACT

Since 1964 the Acoustical Oceanography Branch of the U. S. Naval Oceanographic Office has conducted bioacoustic investigations of deep scattering layers (DSL) in the Atlantic Ocean. The initial investigations before May 1967 were conducted primarily in three regions: the Gulf of Mexico, the southwestern Sargasso Sea, and the Gulf Stream. Biological collections at discrete depths were attempted with a six foot Isaacs-Kidd Midwater Trawl and a Be Multiple Plankton Sampler.

The biological collections were sorted and identified to species (fish and some invertebrates) or to major groups (most invertebrates). The most abundant kinds of fishes collected belong to the families Myctophidae (lanternfishes) and Gonostomatidae (bristlemouths). In general, 2 or 3 species of fishes in a collection were found to be more abundant than the rest, often making up the majority of fish in a sample.

Investigation of the night surface scattering layers in the Gulf of Mexico in March 1967 indicates that the fish in these layers tend to be concentrated in a narrow depth range. Measurements in the Sargasso Sea in November 1965 show some correlation between the depth of occurrence of a deep scattering layer, an oxygen deficient layer, and an abundance of organisms. Collections from both areas as well as in the Gulf Stream agree with the concept that all three are regions of low productivity. Although a strong correlation was not established between DSL occurrence and the biological collections, these initial investigations suggest several findings that merit more intensive study,

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FOREWORD

Detailed knowledge of a variety of oceanographic parameters is required to fully understand the effect of the ocean environment on sound transmission. One parameter which significantly influences sound propagation is the backscattering or volume reverberation caused by marine organisms. The Naval Oceanographic Office is conducting an interdisciplinary research program to investigate the scattering of sound by marine organisms; in particular, this effort includes studies to determine the acoustic, biological and oceanographic properties of sound scattering layers, as well as the relationships between these properties. This report is the first of several concerning the results of biological studies being conducted to investigate volume reverberation in the ocean.

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ACKNOWLEDGEMENTS

Many people took part in these studies and helped on board ship as well as in the laboratory. In particular, Dr. Richard Backus of the Woods Hole Oceanographic Institute was in charge of the identification of material from the earlier collections; Dr. Basil G. Nafpaktitis of the University of Southern California identified the lanternfishes of the genera *Diaphus* and *Lobianchia*; Dr. Giles W. Mead of the Museum of Comparative Zoology at Harvard identified the specimens of *Pterycombus brama*; Mr. Ronald C. Baird, also at Harvard, checked the identification of the hatchetfishes, family Sternoptychidae; Mr. Bert N. Kobayashi of the Scripps Institute of Oceanography identified the fishes of the genus *Cyclothone*; and Dr. Robert H. Gibbs, Jr. and Dr. Stanley H. Weitzman of the United States National Museum checked the identification of many of the other bathypelagic fishes.

To all these people we extend our sincere appreciation. In addition we thank our colleagues for many stimulating discussions concerning interpretation of the data.

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INTRODUCTION

Since November 1964, the U. S. Naval Oceanographic Office has been conducting an intensive investigation of volume reverberation caused by marine organisms in the oceans. Practically speaking, volume reverberation can be defined as the masking of desired target returns by marine organisms which, by virtue of their sound scattering properties, intrude upon the acoustic domain of the Navy. The volume scattering strength of the water column is required to evaluate sonar performance in a given area. Our goal, however, is ultimately to provide a prediction scheme which will take into account the fact that scattering strength values show geographic, diel, and seasonal variations, reflecting the biological character of the phenomenom. Implicit in this requirement for prediction, then, is the need to understand the environmental and biological factors which cause variability in scattering strengths.

The results presented in this report are based on biological, environmental, and acoustic data collected during the preliminary research cruises conducted by this Office in the western North Atlantic Ocean before May 1967 (Figure 1). Most of the acoustic data, and some environmental data have already been reported (Gold, 1966; Farquhar, 1966; Gold and Van Schuyler, 1966; Van Schuyler, 1967; Van Schuyler and Hunger, 1967). The limitations imposed by collecting methods do not permit firm conclusions about causal relationships. However, analysis of the data can indicate guidelines for future work on this problem. We have also indulged in some speculative considerations based on one series of measurements east of the Bahama Islands (Gold and Van Schuyler, op. cit.). A list of the operations and stations at which biological collections were made is included (Appendix A) along with a check list of the species of fishes collected (Appendix B).

METHODS

The biological collections before March 1967 were made with a Bé Multiple Plankton Sampler (MPS). Collections taken during a cruise in March-April 1967 were made using a six-foot Isaacs-Kidd Midwater Trawl (IKMT) with a General Motors Mark III Discrete Depth Plankton Sampler (DDPS) attached to the cod end. The Bé MPS is pressure actuated and has three open-closing plankton nets, each programmed to open and close at specified depths (Bé, 1962). The General Motors DDPS is an electrically operated four-chambered sampling device which permits samples to be taken at discrete depths (Aron et al., 1964). Electronics housed in the spreader bar of the net telemeter information back to the ship about the depth of the net and in situ temperature, but because the pressure sensor was limited to a depth of 500 meters, all of the tows taken were shallow.

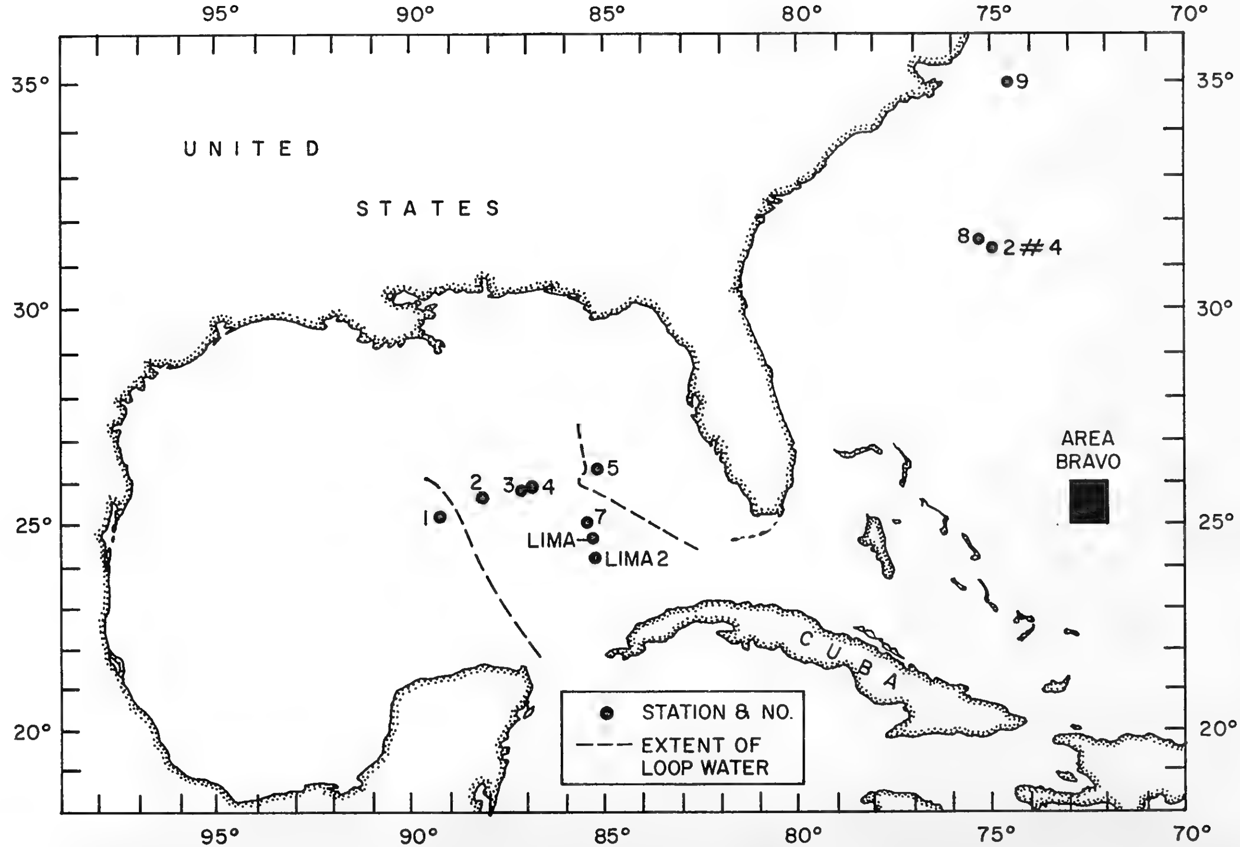

FIGURE 1. LOCATIONS OF BIOACOUSTIC STATIONS, NOVEMBER 1964 TO MAY 1967.

The first (labeled A) and third (C) samples taken with the DDPS were typically horizontal, while the second (B) and last (D) were oblique. The configuration of the towpath for collection 7-TI (Figure 2) is nearly ideal because the two horizontal samples (A and C) show almost no vertical excursion. The oblique samples (B and D) are of little value in determining precise depth limits of occurrence of organisms. The final oblique sample to the surface is of particularly little value since usually the shortest possible time is used in getting the net up to the surface where it fishes and bounces around for varying lengths of time before it can be brought aboard. Nevertheless, keeping these limitations in mind, the oblique samples may often give important indications of animal abundances.

The fish from all collections were sorted and identified to species. The invertebrates from all collections except the March-April 1967 cruise were sorted to major groups. The biological data were analyzed on the basis of geographic area.

Knowing the approximate speed of the ship, the length of time the net was towed for each sample and using Pearcy and Laurs' (1966) figure of 2.89 m^2 for the mouth opening of the six-foot IKMT, with their estimated efficiency of 85 percent, it was possible to calculate the volume of water filtered. Estimates were then made of fish concentration per 1000 m^3 of water excluding larval and post larval specimens. The MPS had a mouth opening of 0.5 m^2 and the efficiency was assumed to be 100 percent.

Explosive acoustic measurements of volume reverberation were made during all cruises discussed above. During the cruise in March-April 1967, when the quality of the biological data was best, an intermittent loss of sensitivity developed in the hydrophone and the acoustic data eventually had to be discarded.

RESULTS

A. Gulf of Mexico

Collections in the Gulf of Mexico were made on two cruises: June 1966 aboard the USNS LYNCH (T-AGOR-7) and March-April 1967 aboard the USNS SANDS (T-AGOR-6). The LYNCH took only four oblique open net hauls from 90 meters to the surface during the night, whereas much more data are available from the SANDS trip.

Oceanographically, the eastern part of the Gulf of Mexico is dominated by a current loop that is part of the Yucatan Current -- Florida Current -- Gulf

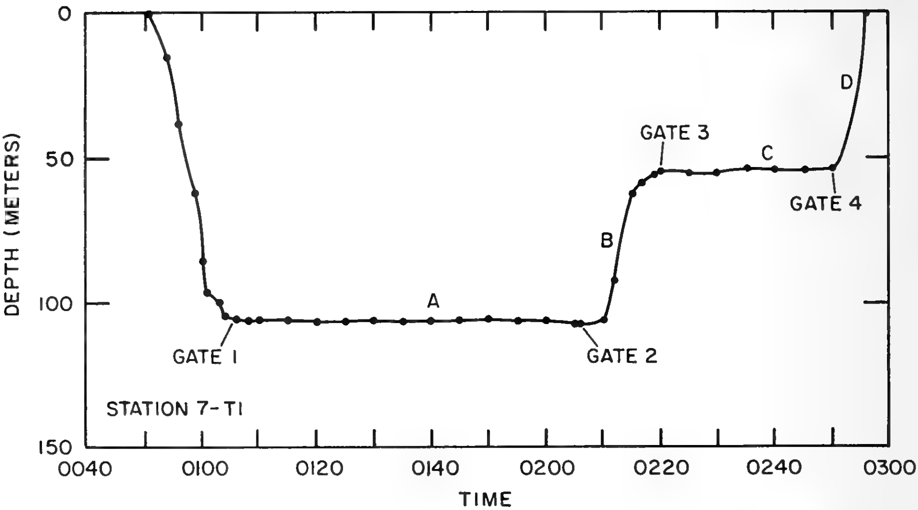

FIGURE 2. SCHEMATIC TOWPATH OF TOW 7-T1, 6 FT ISAACS-KIDD MIDWATER TRAWL WITH DISCRETE DEPTH PLANKTON SAMPLER, GULF OF MEXICO, 28 MARCH 1967.

Stream complex. The approximate limits of this loop water, as delineated by the 22°C isotherm for 50 meters, in the vicinity of collecting stations 1 through 7 are indicated in Figure 1. The loop water is characterized by higher salinity and temperature with a pronounced peak centered at around 200 meters on T-S diagrams. Stations 1 and 5 are outside the loop and stations 2, 3, 4, and 7, as well as stations Lima and Lima 2 are in the loop.

As expected, all of the shallow tows taken in the daytime contain practically no fish, even when the tow was taken exactly at a depth that corresponded to a weak scattering layer on the depth recorder. The fish that were taken were predominantly small, mostly juveniles or larvae, but included a few small myctophids, most often Notolychnus valdiviae and a few species of Diaphus, and a few small, silvery gonostomatids, mostly Bonapartia pedaliota.

The shallow tows taken in the surface scattering layer at night, after the DSL had made its evening ascent, all contained much heavier catches than the daytime tows. Four of the tows are directly comparable. Tows 1-T2 and 5-T1 were on either side of the loop water while tows 3-T1 and 7-T1 were in the loop water.

An examination of the catches of fish (excluding larvae and post-larvae) in the deeper portions of the four tows mentioned above (Figure 3), shows that four of the samples have relatively high concentrations ranging from about 2 to 3.3 fish per 1000 m^3 of water, as opposed to about 1 fish per 1000 m^3 of water for most of the other samples. A diagrammatic depth distribution and configuration of the tow paths with the four higher concentration samples shaded (Figure 4) shows that these four samples were all collected between the depths of 80 to 170 meters. Because three low concentration collections were between depths of 140 and 170 meters, the heavier concentration of fish may be characterized as occurring between the depths of 80 and 140 meters. The fact that samples 3-T1-C and 1-T2-C both were taken in the same depth range and the latter had a higher fish concentration may be related to the fact that it was taken in cooler water. Indeed, other possible evidence for a rise to shallower depths in cooler water is that both deep horizontal samples outside the loop water, 1-T2-A (60.5° to 61.5°F) and 5-T1-A (59° to 62°F), as well as sample 5-T1-B (62° to 70°F), contained specimens of a hatchetfish Argyropelecus aculeatus. Samples 1-T2-A and 5-T1-B also contained a melamphaid, Melamphaes simus. Both of these species tend to be deeper living midwater fish. In the loop water, the deep sample 3-T1-A (73.5° to 76°F) contained neither of these species. Thus, in the cooler water outside the loop, these species were caught at relatively shallower depths.

The great majority of the fish in the four samples that contained the heavy concentrations were myctophids. From 62 percent to 100 percent of the

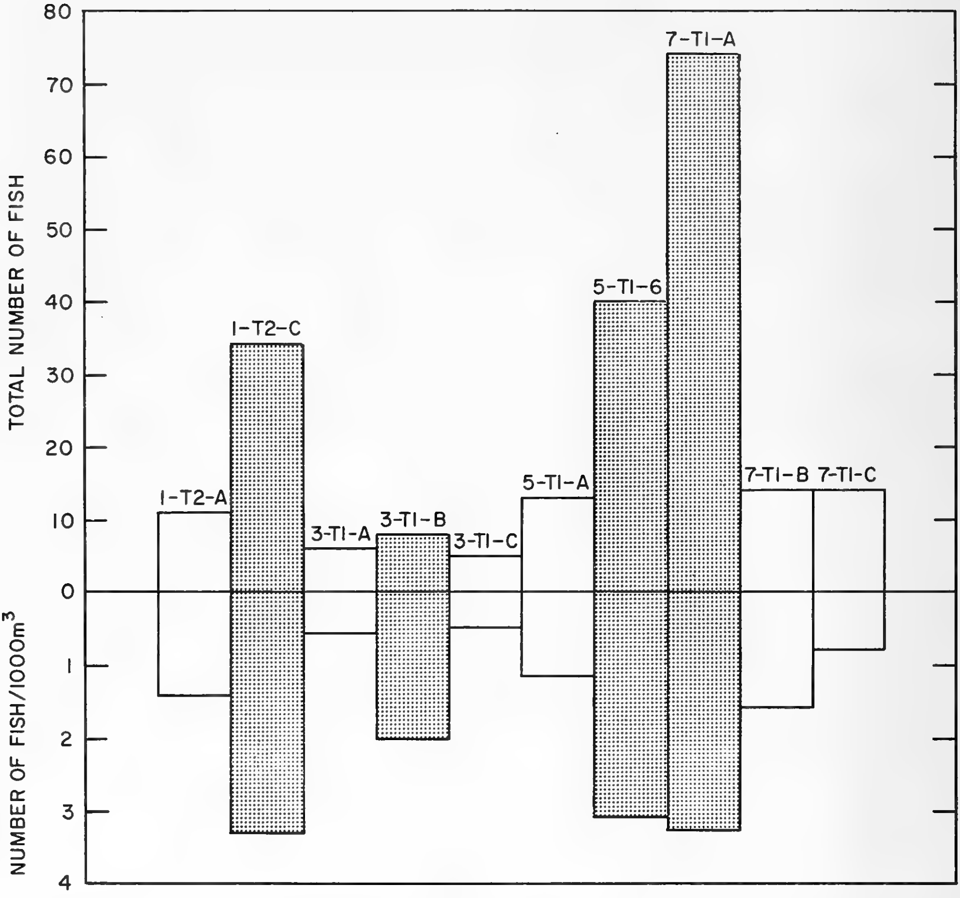

FIGURE 3. TOTAL NUMBERS AND CONCENTRATION OF FISH IN COMPARABLE NIGHT COLLECTIONS, 6 FT IKMT, GULF OF MEXICO, MARCH 1967. HIGH CONCENTRATION COLLECTIONS SHADED.

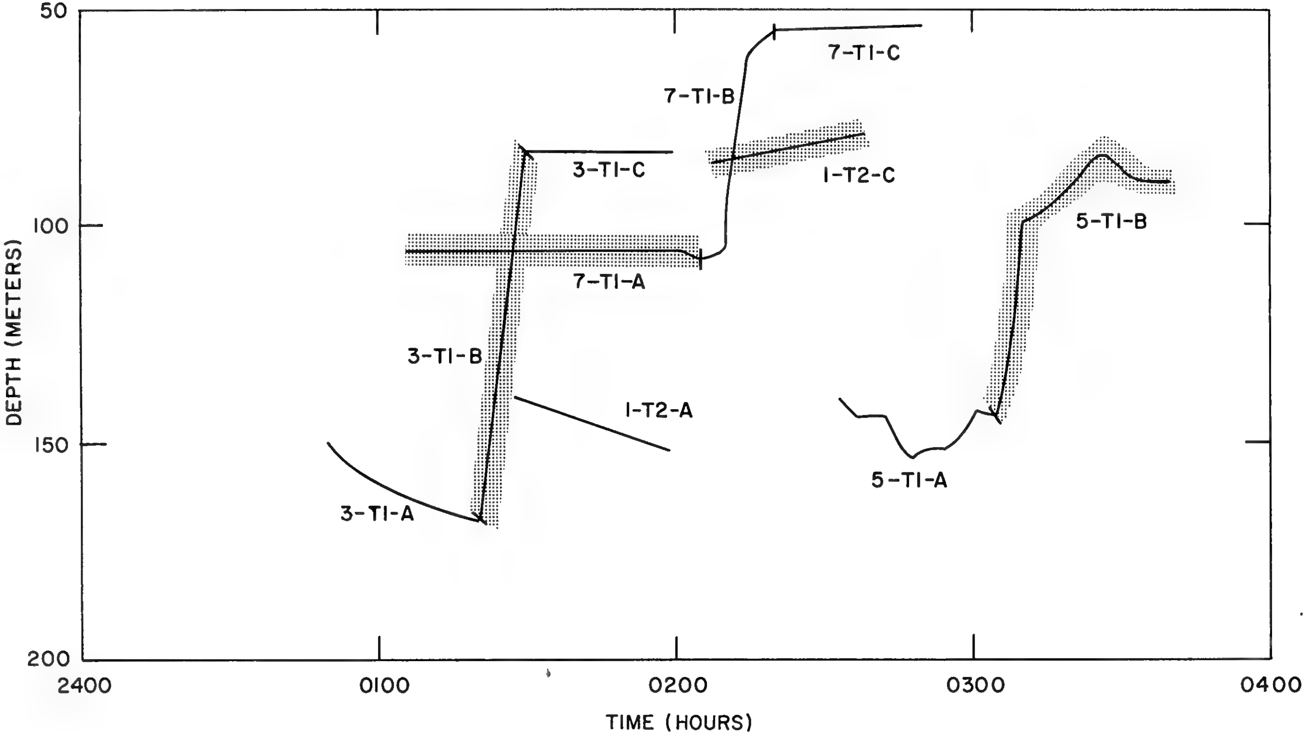

FIGURE 4. SCHEMATIC TOWPATHS OF COLLECTIONS IN FIGURE 3 WITH SAME COLLECTIONS SHADED.

specimens and from 57 percent to 100 percent of the species were myctophids. In the collections with lower fish concentrations the shallower samples also contained a large proportion of myctophids. However, in the deep collections outside the loop water the percentages of specimens and species of myctophids declined and larger number of gonostomatids as well as other groups were represented.

The entire increase in numbers of fish in 7-T1-A, the heavy concentration sample of Tow 7, is due to an increase in the numbers of three species: *Diaphus splendidus*, *Lepidophanes guntheri*, and *Notolychnus valdiviae* (Figure 5). These same species occur in all the other samples in that tow, but in small numbers only. This same pattern is repeated in two out of the three other heavy concentration samples: a few species make up the great percentage of the specimens though the species involved are different. In sample 1-T2-C, *Lepidophanes guntheri*, *Notolychnus valdiviae*, and *Notoscopelus resplendens*, account for 74 percent of the specimens but only 38 percent of the species, and in sample 5-T1-B, *Notolychnus valdiviae*, *Diaphus mollis*, and *Vinciguerria poweriae* account for 50 percent of the specimens but only 17 percent of the species. All of the above mentioned species are myctophids except the gonostomatid *V. poweriae*.

An examination of the depth recorder record from Tow 7-T1 (Figure 6) shows no prominent feature at the depth of sample 7-T1-A, 106 to 108 meters. Examination of the depth recorder records taken in conjunction with the other tows indicates the same situation. There are also no differences between the depth recorder records made in the loop water and those made outside the loop water.

There are less data available from the shallower portions of the night tows in the Gulf of Mexico and analysis of the samples indicates a more complex situation. Three of the six samples have high concentrations of fish per 1000 cubic meters of water sampled (Figure 7). Two of these three samples are oblique tows to the surface while the other sample is a horizontal sample (Figure 8). There is some indication of a layer of greater fish concentration between 50 meters and the surface, but if such a concentrated layer exists, it must be discontinuous or patchy to account for the low fish concentration in sample 3-T1-D. The very high concentration of fish in sample 1-T2-D may be the result of a handling error in the laboratory.

There were four comparable night tows taken by the LYNCH in July 1966 in the Gulf of Mexico at two stations: Lima and Lima 2. All were made using the open MPS and were oblique net hauls from 90 meters to the surface. The fish concentrations estimated from the LYNCH data are in fair

	HYGOPHUM TAANINGI	DIOGENICHTHYS ATLANTICUS	DIAPHUS BRACHYCEPHALUS	DIAPHUS DUMERILI	DIAPHUS MOLLIS	DIAPHUS SPLENDIDUS	NOTOLYCHNUS VALDIVIAE	LEPIDOPHANES GAUSSI	LEPIDOPHANES GUNTHERI	CERATOSCOPELUS WARMINGI	NOTOSCOPELUS CAUDISPINOSUS	NOTOSCOPELUS RESPLENDENS	POLLICHTHYS MAULI	CHAULIODUS SLOANI
7-TI-A		1 16 mm		1 23 mm	1 10 mm	28 13-27 mm	13 15-21 mm		23 16-43 mm	1 54 mm	1 19 mm	2 25 mm	2 30-37 mm	1 68 mm
7-TI-B	1 22 mm			1 17 mm		2 13-14 mm	3 15-19 mm	1 15 mm	1 22 mm					
7-TI-C	2 35 mm		1 12 mm			1 17 mm	3 16-18 mm		2 22-48 mm					
7-TI-D	1 28 mm			2 17-18 mm		1 15 mm	2 15-18 mm		1 33 mm				1 22 mm	

FIGURE 5. NUMBERS AND STANDARD LENGTHS OF FISH CAUGHT DURING TOW 7-T1, 28 MARCH 1967, GULF OF MEXICO (ALSO SEE FIGURE 2).

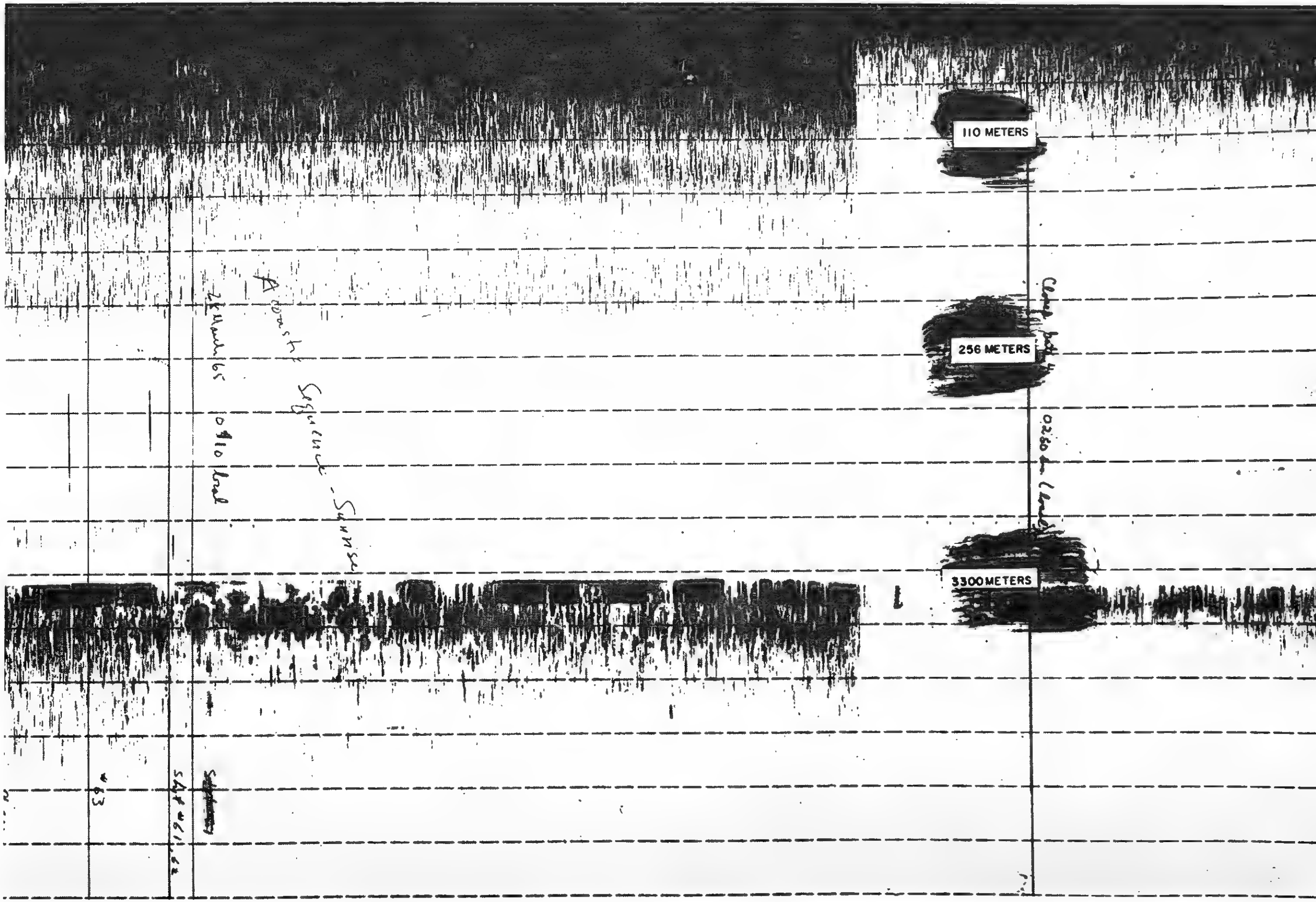

FIGURE 6. DEPTH RECORDER RECORD OF SURFACE SCATTERING LAYER AT END OF TOW 7-T1, 28 MARCH 1967, GULF OF MEXICO, WITH HIGHER GAIN SETTING AT LEFT.

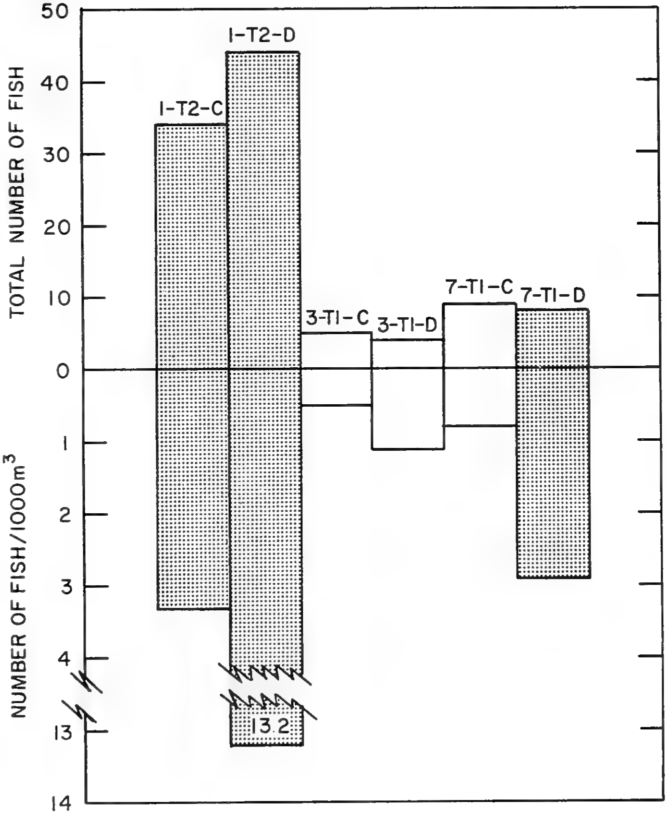

FIGURE 7. TOTAL NUMBERS AND CONCENTRATION OF FISH IN COMPARABLE NIGHT COLLECTIONS EXTENDING TO THE SURFACE, 6 FT IKMT, GULF OF MEXICO, 1967. HIGH CONCENTRATION COLLECTIONS SHADED.

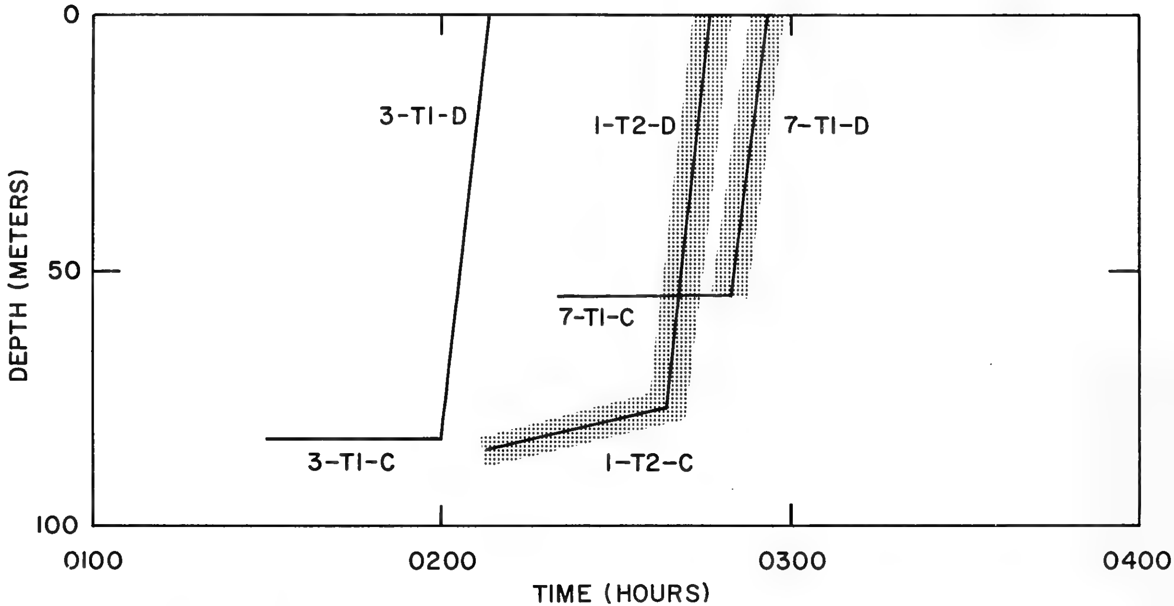

FIGURE 8. SCHEMATIC TOWPATHS OF COLLECTIONS IN FIGURE 7 WITH SAME COLLECTIONS SHADED.

agreement with the results obtained by the SANDS for oblique IKMT hauls to the surface (Table I). Very high proportions of both the species and specimens are myctophids, although the specimens caught in the MPS tended to be much smaller than those in the IKMT.

B. Area Bravo

Area Bravo is located in the southwestern part of the Sargasso Sea. Water depths range from 5300 to 5550 meters with the mixed layer extending down to about 75 meters. The salinity maximum, which marks the core of Subtropical Underwater, is centered close to 100 meters. Eighteen Degree Water, with a mean thickness of about 250 meters, is centered at about 300 meters, and North Atlantic Central Water, underlying this layer, extends to about 900 meters. There were no marked differences in the area in data collected aboard the USNS GILLISS (T-AGOR-4) in November 1965 and the USNS SANDS in March 1966. Surface temperatures in March were cooler by 3-4°C, surface salinities were about 0.2‰ higher, and Eighteen Degree Water and North Atlantic Central Water both were somewhat shallower compared to November. During November, the main oxygen minimum (3.44 ml/L) occurred at about 810 meters (Figure 9). No oxygen data are available for March, but historical data show the oxygen minimum to lie between 800-950 meters. A complete description of oceanographic conditions in Area Bravo is given by Hunger (1969).

Collections are available from two trips to Area Bravo. There are 10 comparable nighttime tows from the surface scattering layer, three made by the USNS GILLISS and seven by the USNS SANDS, all using the Bé MPS. All ten hauls were oblique open net hauls from the surface to as deep as 140 meters.

All three GILLISS tows contained few fish (Table II-A). In Tow 1C, the only tow that had any appreciable numbers of individual species, *Cyclothone braueri* accounted for five out of the total of fifteen fish caught, or 33 percent, and the myctophid *Lepidophanes gaussi*, accounted for another 40 percent of the total catch. In the other two tows, the catch was mostly made up of single representatives of different species. Out of the twelve different species of fish taken in all three tows, only three species were found in two or more different tows. These were one gonostomatid, *Pollichthys mauli* and the myctophids *Notolychnus valdiviae* and *Lepidophanes gaussi*. The number of myctophids, however, considered both as percentage of species and percentage of specimens, are lower than in comparable collections from the Gulf of Mexico. Only in collection 3D were more than 50 percent of the fish myctophids and even here only 63 percent of the species and 59 percent of the speciments were myctophids.

TABLE I

ESTIMATED FISH CONCENTRATIONS IN COMPARABLE SHALLOW NIGHT CATCHES WITH THE BÉ MPS IN THE GULF OF MEXICO, JUNE 1966, USNS LYNCH AT LOCATIONS LIMA AND LIMA 2

TOW	DEPTH (m)	TOTAL FISH CATCH	FISH/1000 m^3
Lima # 3	90-0	30	13.3
Lima # 4	90-0	11	4.8
Lima 2 #2	90-0	10	5.1
Lima 2 #3	90-0	16	7.1

TABLE II

ESTIMATED FISH CONCENTRATIONS IN AREA BRAVO BASED ON SHALLOW NIGHTTIME CATCHES WITH THE BÉ MPS

TOW	MAXIMUM DEPTH (m)	TOTAL FISH CATCH	FISH/1000 m^3
A. November 1965, USNS GILLISS.			
2A	60	7	2.1
1C	35	15	3.8
3D	60	17	3.6
B. March 1966 - within upper 50 meters, USNS SANDS.			
4A	50	13	8.9
9A	50	1	0.8
14B	40	10	4.6
C. March 1966 - within upper 140 meters, USNS SANDS.			
3A	100	5	2.2
7A	125	12	8.9
8A	140	5	3.7
13B	95	22	8.7

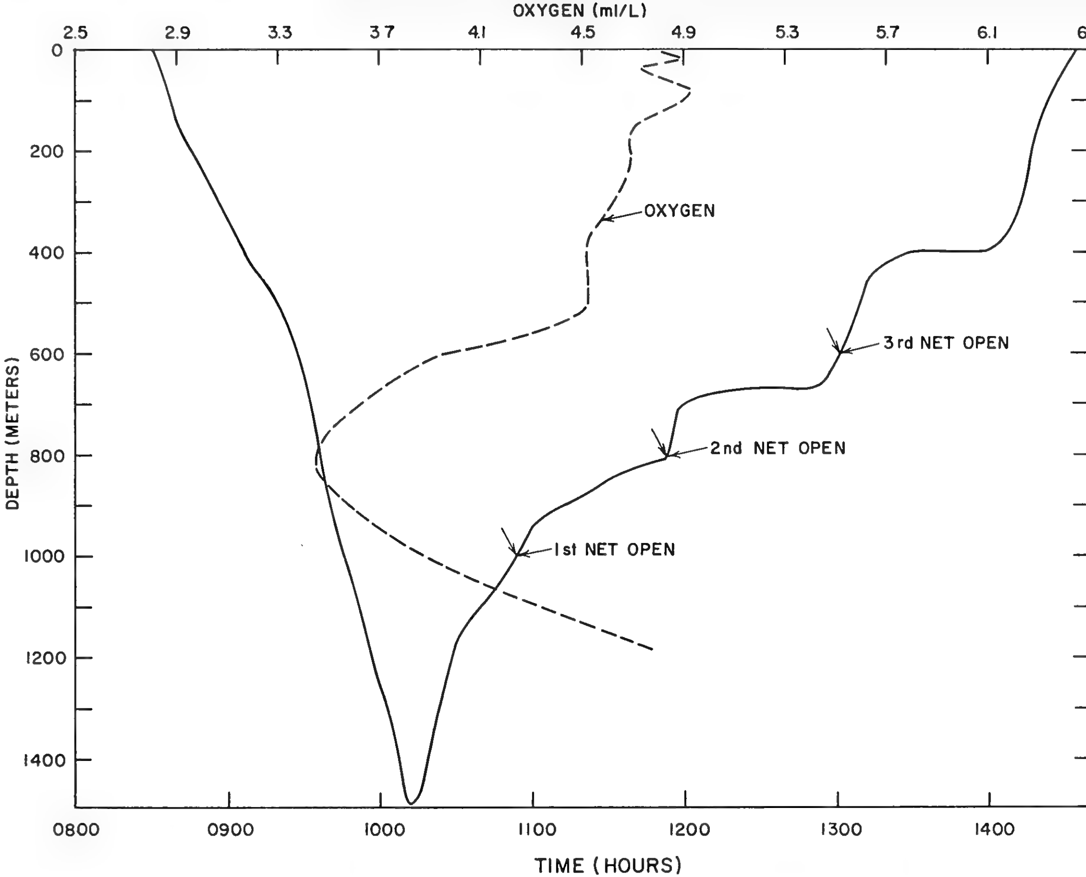

FIGURE 9. SCHEMATIC TOWPATH FOR TOW 1-D, BE MULTIPLE PLANKTON SAMPLER, AREA BRAVO, 22 NOVEMBER 1965, SUPERIMPOSED ON CURVE OF DISSOLVED OXYGEN CONCENTRATION.

Three of the SANDS collections are considered together, since they sampled from 50 meters to the surface and thus are more directly comparable with the three GILLISS collections. The relative proportions of myctophids are small, as are the total numbers of fish and the numbers of individuals of each species, resulting in quite variable estimated fish concentrations (Table II-B). Only 4-A, which contained six specimens of Lepidophanes gaussi out of 13 fish, had any appreciable numbers of any one species. On the basis of these few individuals, there are no apparent differences between the GILLISS' hauls which were taken in November and the SANDS' hauls which were taken in March.

The four remaining surface scattering layer hauls were taken by the SANDS from the surface down to depths of 95 to 140 meters. As in the GILLISS and SANDS collections discussed above, the total numbers of fish as well as the numbers of individuals of each species are low and the estimated fish concentrations are variable (Table II-C). In collection 7A four specimens of Notolychnus valdiviae and four specimens of Lepidophanes gaussi were taken out of a total of 12 fish. In this collection two-thirds of the species and 83 percent of the specimens were myctophids. Two of the three fish taken in Tow 8A were also myctophids. In collection 13B four specimens of Gonostoma elongatum and four specimens of Lestidiops affinis were taken out of a total of 22 fish, while all other species were represented by one or two individuals.

Several daytime hauls from the surface to about 110 meters or less on both the GILLISS and SANDS trips yielded only a few larval or post larval fish.

On the GILLISS trip, several hauls attempted to use the discrete depth sampling capabilities of the MPS (Appendix A). However, the sampler was cocked properly on only two occasions, both of which were day hauls; one to a depth of 450 meters and the other to a depth of 1000 meters. The shallower haul, 1-A, contained no fish larger than larvae or post larvae in any of the three nets. However, the deep haul, 1-D contained substantial numbers of fish.

Tow 1-D samples the depth intervals of 1000 m - 800 m, 800 m - 600 m, and 600 m to the surface (Figure 9). The estimated fish concentrations are extremely variable (Table III). Large numbers of Cyclothone braueri and C. microdon are primarily responsible for the high fish concentration in the deep sample (Figure 10). Although 46 percent of the species in the sample are myctophids they make up less than 10 percent of the specimens. However, the two most abundant myctophids, Notolychnus valdiviae and Lepidophanes gaussi, were consistently among the most abundant species in the Area Bravo night surface scattering layer collections reported above.

TABLE III

ESTIMATED DAYTIME FISH CONCENTRATIONS AT THREE DEPTH INTERVALS IN TOW 1D WITH THE BÉ MPS, AREA BRAVO, NOVEMBER 1965

SAMPLE	DEPTH (m)	TOTAL FISH CATCH	FISH/1000 m^3
Shallow	600-0	2	0.4
Middle	800-600	17	4.6
Deep	1000-800	96	29.6

The invertebrates that were separated and enumerated in the open net oblique hauls taken by the GILLISS between the surface and about 110 m show great variability in numbers between the day and night collections with no apparent pattern. The invertebrates taken in the oblique open net hauls by the SANDS between the surface and about 140 m tend to be more numerous in the night tows than in the day tows. This is particularly true of the crustaceans in general except that the numbers of carideans seem to remain about the same. The siphonophores, enumerated as numbers of nectophores, vary widely but seem in general to be more numerous in the night hauls. The most striking feature about the numbers of invertebrates in Tow 1-D taken by the GILLISS in the daytime, is that virtually all siphonophores were taken in the shallow sample, 600 m to the surface. The numbers of crustaceans in haul 1-D varied with no real pattern, though identification of the material to species would probably disclose definite depth distributional patterns.

C. Other Western Atlantic Stations

Investigations were carried out at three other stations in the western North Atlantic Ocean, outside of Area Bravo (Figure 1). Stations 2 #4 and 8 were both at the edge of the Sargasso Sea. Station 9 was not far off the coast in the main part of the Gulf Stream.

Oceanographic conditions in the vicinity of Station 8 were quite similar to those in Area Bravo. The hydrographic cast was not successful at Station 9, so little information was obtained about the oceanographic conditions there.

Four net hauls were taken by the USNS LYNCH at the site of 2 #4 (Figure 1) using the MPS. Only Tow 2 # 4, an oblique open night

	Diogenichthys atlanticus	Diaphus effulgens	Diaphus sp.	Notolychnus valdiviae	Lepidophanes gaussi	Lepidophanes pyrsobolus	Cyclothone alba	Cyclothone braueri	Cyclothone microdon	Cyclothone pallida	Cyclothone pseudopallida	Chauliodus danae	Idiacanthus fasciola	Argyropelecus aculeatus	Argyropelecus hemigymnus	Photostomias guernei	Paralepis elongata
1D SHALLOW								1 16 mm							1 8 mm		
1D MIDDLE									10 13-20 mm	1 45 mm	5 27-30 mm						1 41 mm
1D DEEP	1 14 mm	1 11 mm	1 14 mm	2 10-14 mm	3 16 mm	1 18 mm	1 11 mm	48 11-23 mm	25 10-14 mm		5 14-21 mm	2 23-89 mm	2 54-62 mm	1 7 mm	2 7 mm	1 31 mm	

FIGURE 10. NUMBERS AND STANDARD LENGTHS OF FISH CAUGHT DURING TOW 1-D, 22 NOVEMBER 1965, AREA BRAVO (ALSO SEE FIGURE 9).

tow from the surface to about 100 m, caught fish other than larvae or post larvae. It sampled an estimated fish concentration of 3.4 fish per 1000 cubic meters of water. All were myctophids except for a trichiurid Diplospinus multistriatus, while 7 of the 11 myctophids were specimens of Lobianchia dolfleini.

Four tows, two at station 8 and two at station 9, were taken during migration periods of the deep scattering layers. Since the migration and environmental conditions for each tow are unique to that tow, the results from each tow must be examined individually.

Tow 8-T1 sampled the descending scattering layer from 0400 to 0737 hours (local) at a depth of about 103 meters (Figure 11). Gate 4 did not function properly resulting in only three samples. Sample 8-T1-B, taken in the surface scattering layer, had much higher estimated fish concentrations than sample 8-T1-C and D which sampled after the layer had descended (Table IV).

TABLE IV

ESTIMATED FISH CONCENTRATIONS IN COLLECTIONS WITH THE 6-FOOT IKMT AT STATIONS 8 AND 9 IN THE WESTERN ATLANTIC, APRIL 1967, USNS SANDS

SAMPLE	DEPTH (m)	SAMPLING TIME (MIN)	TOTAL FISH CATCH	FISH/1000 m^3
8-T1-A	100-103	55	47	2.79
8-T1-B	103	55	48	2.85
8-T1-C&D	105-0	107	21	0.63
8-T3-A	88	30	2	0.22
8-T3-B	88-86	36	5	0.46
8-T3-C&D	86-0	67	88	4.19
9-T1-A	307-363	78	3	0.14
9-T1-B	307-228	12	0	0
9-T1-C&D	228-0	95	20	0.74
9-T2-A	112-123	30	6	0.75
9-T2-B	118-132	30	2	0.25
9-T2-C	122-132	30	2	0.25
9-T2-D	132-0	40	3	0.26

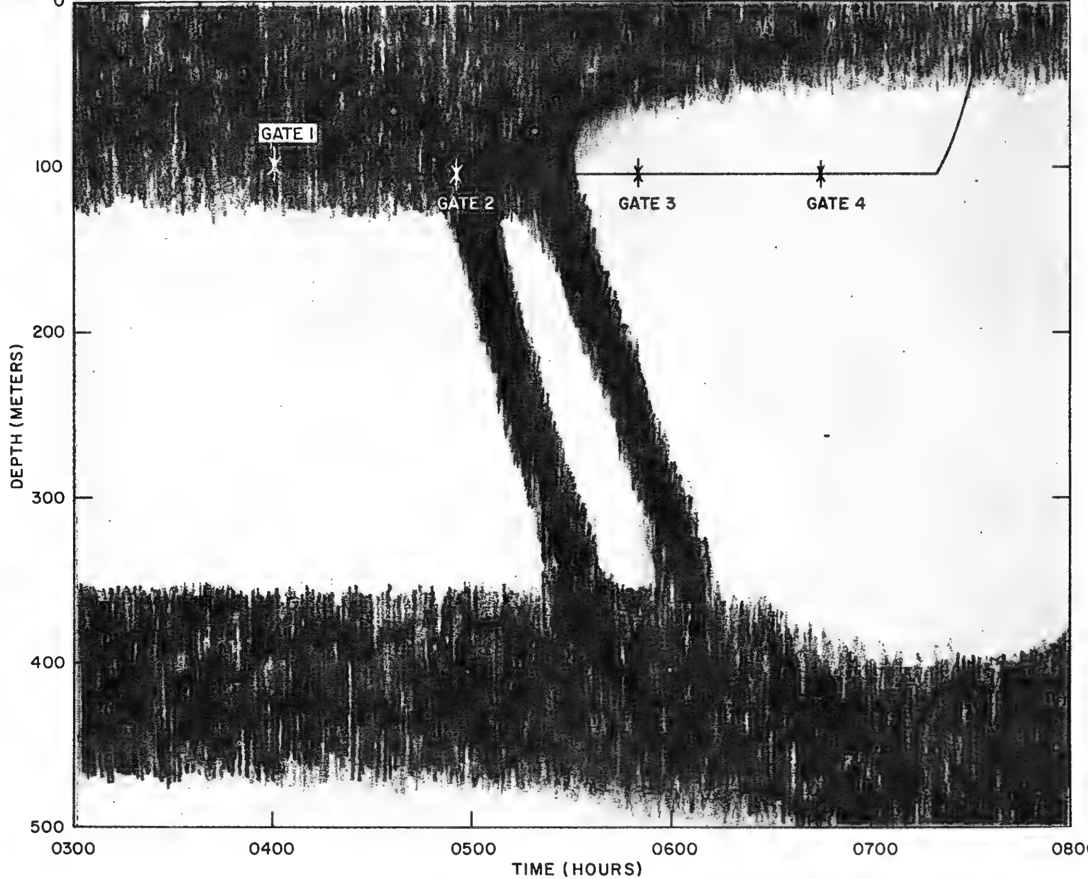

FIGURE 11. SCHEMATIC TOWPATH FOR TOW 8-T1, SUPERIMPOSED ON DIAGRAMMATIC REPRESENTATION OF SCATTERING LAYER CONDITIONS TAKEN FROM THE DEPTH RECORDER RECORD; 6 FT IKMT, STATION 8, 3 APRIL 1967.

The proportions of myctophids in all three samples are high, with the myctophids accounting for 53 percent to 67 percent of the species and 64 percent to 83 percent of the specimens. Specimens of Lepidophanes pyrsobolus are prominent in all three samples, as are specimens of Notolychnus valdiviae in sample 8-T1-A and of Hygophum hygomi and Notoscopelus resplendens in sample 8-T1-B.

Tow 8-T3 sampled the ascending scattering layers at approximately 88 meters, which meant that this tow was also sampling in the lower half of the daytime surface scattering layer before the evening ascent (Figure 12). Unfortunately, gate 4 again malfunctioned resulting in only three samples. However, Table IV shows clearly that sample 8-T3-C and D, during which the main DSL ascent reached the level of the tow, had a much heavier collection of fish than the two earlier samples. No myctophids were taken in the two earlier samples except for a single larva, while in sample 8-T3-C and D myctophids account for 70 percent of the species and 85 percent of the specimens. Three species, all myctophids, were much more numerous than the other fish in the sample: Lepidophanes pyrsobolus, Diogenichthys atlanticus and Ceratoscopelus warmingi. From one to three small specimens of a trichiurid Diplospinus multistriatus were present in every sample of tows 8-T1 and 8-T3, indicating that these small fish may not be part of the diurnally migrating layers.

Tow 9-T1 sampled from 2330 - 0235 hours (local), during which time a weak scattering layer descended gradually from below the level of the surface scattering layer (Figure 13). Another weak, but deeper and narrower, scattering layer descended at the same rate but had faded away by the time the net was in a position to sample it. Thus, 9-T1-A sampled below the descending scattering layer. The only fish it contained were three specimens of a gempylid or snake mackeral, Nesiarchus nasutus, ranging from 245 to 258 mm in standard length. The erratic tow path during this sample may be a reflection of the deep currents of the Gulf Stream. Sample 9-T1-B coincided almost exactly to the depths encompassed by the descending scattering layer but contained no fish other than two eel leptocephali and a postlarval antennariid or frogfish.

Sample 9-T1-C and D from above the descending layer to the surface, caught many more fish than the two earlier samples (Table IV), though the estimated fish concentration is low compared to the heavy samples from station 8. Myctophids accounted for 80 percent of the specimens in the sample, but only single individuals were taken except for ten specimens of Lepidophanes guntheri.

Tow 9-T2 sampled in the lower part of the surface scattering layer, but may have been at the level of the main descending scattering layer for about five minutes during the first part of sample 9-T2-A (Figure 14). As may be seen in Table IV, this sample had the heaviest estimated fish concentration of the four

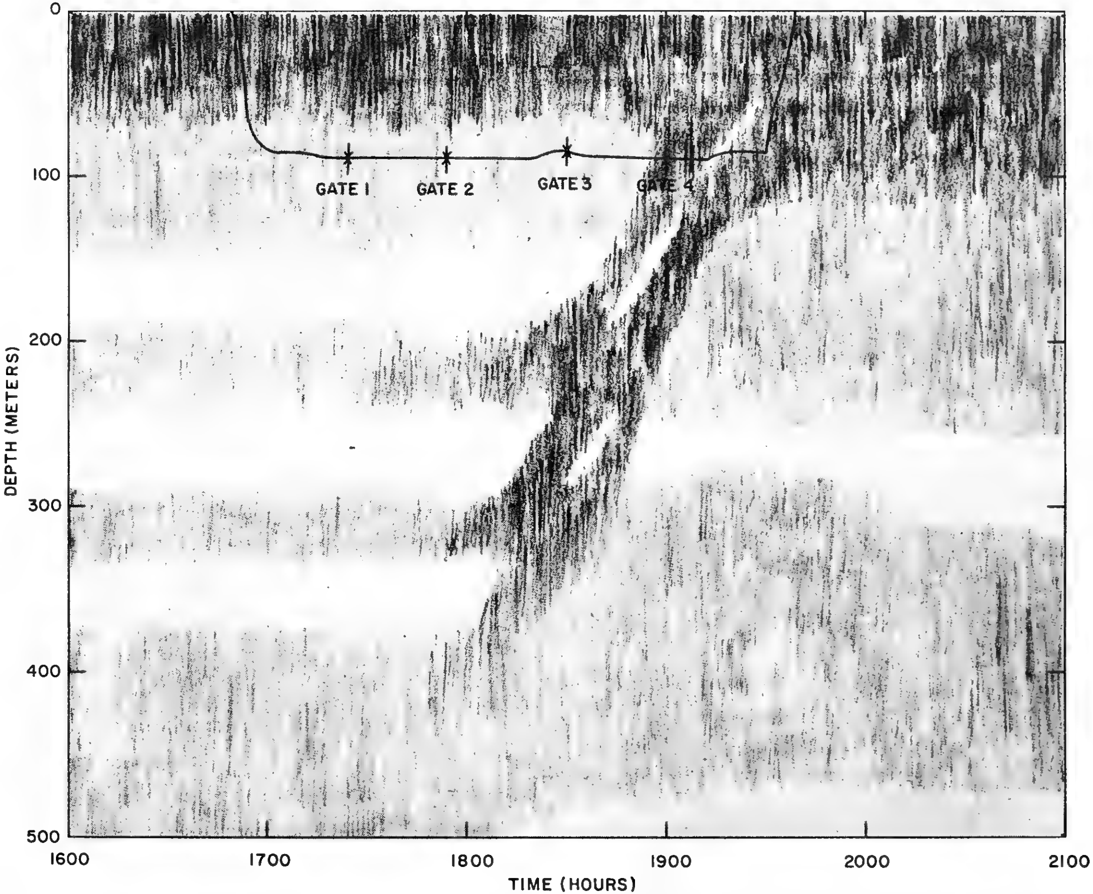

FIGURE 12. SCHEMATIC TOWPATH FOR TOW 8-T3, SUPERIMPOSED ON DIAGRAMMATIC REPRESENTATION OF SCATTERING LAYER CONDITIONS TAKEN FROM THE DEPTH RECORDER RECORD; 6 FT IKMT, STATION 8, 3 APRIL 1967.

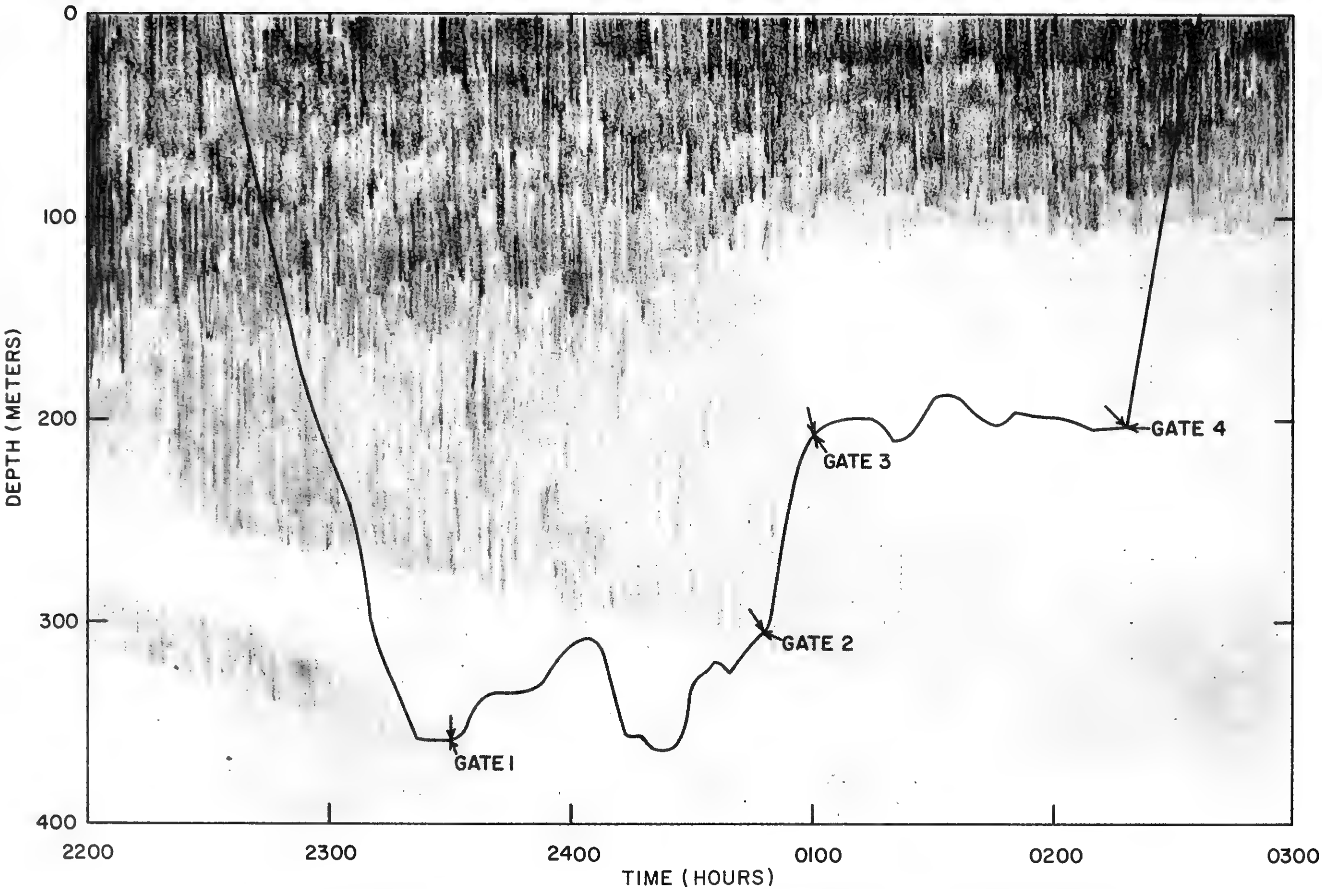

FIGURE 13. SCHEMATIC TOWPATH FOR TOW 9-T1, SUPERIMPOSED ON DIAGRAMMATIC REPRESENTATION OF SCATTERING LAYER CONDITIONS TAKEN FROM THE DEPTH RECORDER RECORD, 6 FT IKMT, STATION 9, 6 APRIL 1967.

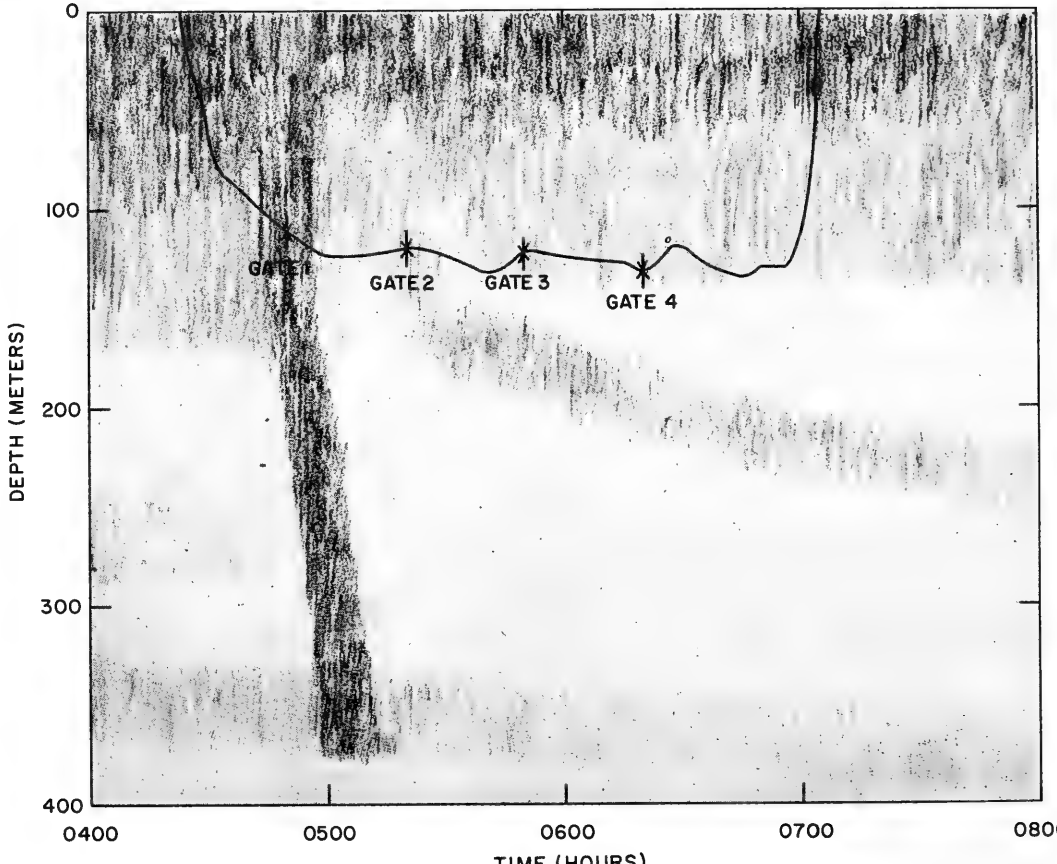

FIGURE 14. SCHEMATIC TOWPATH FOR TOW 9-T2, SUPERIMPOSED ON DIAGRAMMATIC REPRESENTATION OF SCATTERING LAYER CONDITIONS TAKEN FROM THE DEPTH RECORDER RECORD, 6 FT IKMT, STATION 9, 6 APRIL 1967.

from this tow, but a low concentration compared to the three collections at station 8 with heavy concentrations. One each of three species of myctophids were taken in this sample as were two specimens of a gonostomatid Pollichthys mauli. One or two specimens of Pollichthys mauli were also in each of the other three samples but there were no myctophids.

DISCUSSION

Numerous workers have noted the similarity between the vertical distribution patterns of mesopelagic animals and the diel vertical movements of sound scattering layers. Backus et al. (1968), using a submersible, recently demonstrated that a myctophid Ceratoscopelus maderensis is indeed responsible for a peculiar 12-kHz scattering layer known as "Alexanders Acres", recorded regularly in slope water off New England.

Many pelagic fish have gas-filled swimbladders which can resonate when struck by sound waves of the proper frequency. This resonant frequency of the associated gas bubble varies primarily with the depth and bubble size.

The resonant frequency, f_r, of a swimbladder is approximated by Minnaert's equation (Minnaert, 1933) as

$$f_r = \frac{1}{2\pi R} \left(\frac{3\gamma P}{\rho} \right)^{1/2} \qquad (1)$$

where f_r is in cycles/sec, R is the radius, in cm, of a sphere equal in volume to that of the swimbladder, γ is the ratio of specific heats of the swimbladder gas, P is the ambient pressure in dynes/cm^2 and ρ is the density of seawater in gm/cm^3. To account for the energy losses in the resonating fish-swimbladder system, Andreeva (1964) modified the above equation to

$$f_r = \frac{1}{2\pi R} \left(\frac{3\gamma P + 4\mu_1}{\rho} \right)^{1/2} \qquad (2)$$

where μ_1 represents the real part of the complex shear modulus of fish tissue. At depths greater than 200 meters, where $3\gamma P \gg 4\mu_1$, the effect of the fish tissue can be neglected. Using equation (1), Gold and Van Schuyler (op.cit.) computed swimbladder volumes for two scattering layers detected by means of explosive measurements in Area Bravo. The frequency characteristics of these layers, and associated bubble sizes and volumes are summarized in Table V.

TABLE V

CALCULATED VALUES OF SELECTED PARAMETERS FOR TWO DEEP SCATTERING LAYERS RECORDED IN AREA BRAVO, NOVEMBER 1965, USNS GILLISS

DEPTH TO BOTTOM OF LAYER (m)	FREQUENCY RANGE (kHz)	MEAN SWIMBLADDER VOLUME (cc)	RANGE OF SWIMBLADDER VOLUME (cc)	$\bar{R}$* (cm)	RANGE OF R (cm)	RANGE OF FISH LENGTH (cm)
950	6.0 - 5.3	0.7	0.6 - 0.9	0.56	0.53 - 0.6	10.3 - 11.6
610	18.5 - 10.5	0.02	0.01 - 0.06	0.18	0.14 - 0.24	2.7 - 4.7

* R = RADIUS OF SPHERE EQUIVALENT TO SWIMBLADDER VOLUME

Andreeva and Chindonova (1964) simplified equation (2) to

$$f_r = 1.5 \frac{(H + 30)^{1/2}}{(V_{bl})^{1/3}} , \qquad (3)$$

where f_r is in kHz, H is the depth in meters, and V_{bl} is the volume of the swimbladder in mm^3. From Haslett's consideration of fish dimensions (Haslett, 1962), fish volume is related to fish length (L) by the expression

$$V_{fish} = 0.01 \ L^3. \qquad (4)$$

Following Marshall's assumption (1951) that the volume of the swimbladder in a marine fish is about 5 percent of the volume of the fish, the swimbladder volume can be expressed as

$$V_{bl} = 5 \times 10^{-4} \ L^3. \qquad (5)$$

By combining equations (3) and (5) an expression is given for fish length as

$$L = \frac{2 \ (H + 30)^{1/2}}{f_r} , \qquad (6)$$

where L is in cm.

Although Capen's measurements of swimbladders in dissected fish (Capen, 1967) as well as our own, indicate that in bathypelagic fish, the expression $V_{bl} = 0.05 \ V_{fish}$ is not entirely accurate, the direct measurements of swimbladder volume by Kanwisher and Ebeling (1957) agree well with this relationship. Since the term $(H + 30)^{1/2}$ takes fish tissue effects into account as mentioned above, equation (6) can be modified to

$$L = \frac{2 \ (H + 10)^{1/2}}{f_r} \qquad (7)$$

This equation neglects tissue effects for these deep layers, and was used to estimate the range of fish lengths for the two layers (Table V) reported by Gold and Van Schuyler (op.cit.).

As previously discussed, the 1000 m to 800 m sample from tow 1-D in November 1965 yielded the relatively high fish concentration of 29.6 fish/1000 m^3 (Table III), primarily due to the large number of Cyclothone braueri and C. microdon. However, none of the specimens of swimbladder bearing fish collected even approaches 11.0 cm in length, the theoretical size for 5-6 kHz resonant scattering at these depths (Table V). Although the specimens of Cyclothone probably all had gas-filled swimbladders (Marshall, 1960, p. 66), the bubble size would be too small for these fish to contribute to resonant scattering at 5-6 kHz.

Fish concentration in the middle sample (800-600 m) was about seven times less than the deep sample. Although the larger specimens of Cyclothone fall in the proper size range, as computed above, for the 10.5-18.5 kHz layer, these fish also are in the size range where the gas gland and rete have degenerated and the lumen of the swimbladder has become invested with fat (Marshall, op.cit.). Thus, it is highly unlikely that Cyclothone is an important contributor to scattering in this layer.

Gold and Van Schuyler (op.cit.) reasoned that the layers they observed at 950 and 610 m did not migrate since the peaks representing these layers on the logarithmic reverberation trace did not shift during migration periods. It is possible, however, that these layers or portions of them did migrate later, after the peak on the reverberation trace was masked by an increase in reverberation due to shallower migrant scatterers.

With regard to the six-foot Isaacs-Kidd Midwater Trawl collections, it is interesting that samples 8-T1-C and D contains as many mesopelagic fish as it does, since, according to the echosounder record, the main scattering layer descended past the sampling depth almost 30 minutes earlier. Most of the specimens are medium sized myctophids similar to those in the two earlier samples of that tow. With the exception of one specimen of Notolychnus valdiviae, all of the individuals in this sample are too large according to Equation (7), to contribute to 12 kHz scattering in the upper 100 meters of the water column. However, though these individuals do not account for 12 kHz scattering they may be important contributors to scattering at lower frequencies. This situation in tows 8-T1-C and D illustrates once again, that although echosounder recordings generally provide an excellent graphic display of scattering layers, they portray scattering only at frequencies near the operating frequency of the instrument, usually 12 kHz.

Besides the obvious correlation of scattering layer movements with changes in light intensity, scattering layers have been found associated with an oxygen minimum layer (< 0.08 ml 0_2/L.) in the Arabian Sea by Kinzer (1967). He also reported the capture of myctophids and gonostomatids in large numbers from these scattering layers. Kanwisher and Ebeling (op.cit.) found an abundance of hatchetfish (sternoptychids) in the oxygen minimum (< 0.25 ml 0_2/L.) of the eastern tropical Pacific. Many other authors including Marshall (1954, p. 176) have noted the frequent abundance of animals, particularly zooplankton, in oxygen-poor waters and the frequent association of both with sound scattering layers.

An oxygen deficient layer was found between about 600 and 1000 meters in Area Bravo (Figure 9): the depths encompassed by the middle and deep samples of tow 1-D. Unfortunately, the depth of minimum oxygen concentration and the opening depths of the three sample nets, are not known precisely. Thus, we cannot exactly correlate fish abundance with the O_2 minimum, but only note that the deep sample with the heavy fish concentration came from the lower part of the oxygen deficient layer.

It is clear that in all three regions, the most numerous diurnally vertically migrating fish are the lanternfish or myctophids; although, the bristlemouths or gonostomatids are prominent and, at times, may exceed the myctophids in numbers. Along with Pearcy and Laurs (op.cit.) and others we also found a predominanace of only a few species within a collection. To some extent this, as well as the diurnal distribution pattern, is a reflection of gear selectivity, but it also reflects the actual distribution. Pearcy and Laurs (ibid) discussed the problem of gear selectivity and net avoidance by fish and attempted quantitative estimates of avoidance. Many others have discussed the problem of gear selectivity in capturing other animals, even including, rather surprisingly, copepods (Grice and Hulsemann, 1968).

Although our estimates of fish concentrations indicate that the Be Multiple Plankton Sampler catches as many or more fish as the six-foot Isaacs-Kidd Mid-water Trawl, when the volume of water filtered is taken into account, the fish caught by the six-foot IKMT are much larger than those taken by the MPS. The MPS catches relatively more small fish. This may be because the liner of the IKMT is much coarser mesh than the MPS, while the mouth opening of the MPS is too small to catch most large fish. Harrisson (1967), in discussing the methods for sampling mesopelagic fish, pointed out the shortcomings of even the 10-foot IKMT for taking a representative sample of the mesopelagic fish fauna. He also discussed the increased catches that the 10-foot IKMT made during oblique hauls as compared to horizontal hauls. He attributed this largely to the increased speed of the net coupled with the behavior and swimming abilities of the hatchetfish on which he based his discussion. Our data from the Gulf of Mexico indicate that many of the oblique hauls also had substantially larger catches than many of the horizontal hauls. The oblique hauls of short duration moved as much as 12 to 20 percent faster than the horizontal net hauls, although the ship speed remained constant. This increased speed must have some effect on increasing the catch in the oblique hauls. However, this cannot explain the low fish concentrations in some of the oblique hauls, nor the high fish concentration in horizontal haul 7-T1-A, which we interpret as having sampled within a layer of greater fish concentration. Thus, it is obviously necessary to invoke either chance or discontinuities (patchiness or layering) in the distributional patterns of the fish in order to adequately explain the observations. Many more samples are required to adequately assess the comparative effectiveness of oblique versus horizontal hauls, as well as the vertical and horizontal distributional patterns of mesopelagic animals.

Harrisson (op.cit.) is undoubtedly correct in advocating a balanced program of several different techniques for obtaining information about the mesopelagic fauna. However, one great difficulty with a diversified sampling program is in interpreting the data quantitatively. This must be done so that biological measurements can be compared with quantitative acoustic measurements of volume reverberation. It must also be done in order to assess the importance of productivity as a criterion for predicting volume reverberation conditions.

Past measurements of productivity in the open ocean that appear in the literature are subject to varying interpretations. This is particularly true where the accuracy of finely detailed quantitative measurements is concerned. However, the overall picture of productivity in the world ocean as shown by Fleming and Laevastu (1956, p. 185), Steeman Nielsen and Jensen (1957), and Ebeling (1962, p. 146), is not unreasonable. The classification of tropical and subtropical waters by Steeman Nielsen and Jensen (op. cit., p. 89) is useful, though perhaps an oversimplification, since they point out that there are no definite boundaries between the regions. They distinguish four regions, based on the rate of organic production as measured in grams of carbon produced per square meter per day. The two of higher productivity, exemplified by the southern part of the Benguela Current for Class I and the divergences caused by the Equatorial Counter Currents for Class II, do not really concern us here. Class III with a daily organic production of 0.1 - 0.2 g C/m^2/day includes most of the tropical and subtropical regions of the ocean, and probably both the Gulf of Mexico and Area Bravo fit into this category. Class IV is exemplified by the central part of the Sargasso Sea with a rate of organic production of about 0.05 g C/m^2/day. Riley's (1939) proposal that the Sargasso Sea may be considered a productive area was discussed and refuted by Steeman Nielsen (1954, p. 325). Since Area Bravo is at the western side of the Sargasso Sea, it might more correctly be considered as being in a transitional region between Class III and Class IV regions. There have been no primary productivity measurements published from the central Gulf of Mexico, but the few papers (Riley, 1938; Marshall, 1956; Steele, 1964; Wood and Corcoran, 1966) that deal with various aspects of productivity in the Gulf of Mexico, as well as studies of current patterns (Armstrong and Grady, 1967) and the distribution of nutrients

(Van Schuyler and Hunger, op.cit.), all indicate that this area would probably belong to Class III. In either case, both the Gulf of Mexico and Area Bravo may be considered as being in regions of rather low productivity.

The relationship between primary productivity and standing crop, particularly standing crop of zooplankton, is problematical (Strickland, 1960, p. 101). Steeman Nielsen and Jensen (op.cit., p. 117) point to a high correlation between their measurements of primary productivity and standing crops of both phytoplankton and zooplankton. Jespersen (1923, Figure 1 and 1935, Figure 4) showed that the central Sargasso Sea, at least, had much lower macroplankton volumes than the surrounding waters. Our own collections in both Area Bravo and the Gulf of Mexico, although not very stringent in a quantitative sense, contained much smaller quantities of organisms than our collections for comparable lengths of time in an area of high productivity, the Norwegian Sea. Thus, our data are at least consistent with the concept that both Area Bravo and the Gulf of Mexico are regions of low primary productivity.

CONCLUSIONS

From our midwater collections in the Gulf of Mexico and western North Atlantic we can conclude the following:

1. The fish in the night surface scattering layers in the Gulf of Mexico tend to be concentrated in a narrow depth range. This depth of abundance may depend somewhat on the water temperature.

2. Myctophids and gonostomatids are the most abundant kinds of fish in our collections.

3. A few species, often only 2 or 3, out of the total number of fish caught, usually make up the majority of the fish catch.

4. No consistent correlation is found between the depths, kinds, and numbers of animals taken and occurrence of 12 kHz deep scattering layers. At least part of the reason for this is the obvious inefficiency of the nets that were used to sample the organisms at a given depth.

5. The concept that the Gulf of Mexico, Gulf Stream, and Sargasso Sea waters are of low productivity, is upheld by the relative sparseness of organisms in our collections.

6. Our collections are consistent with previously reported correlations between an oxygen minimum layer and an abundance of organisms.

7. An intensive investigation of the deep scattering layers and mid-water organisms in these areas is required in order to confirm or refute the patterns indicated by these preliminary investigations.

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APPENDIX A

LIST OF STATIONS WITH STATION DATA AT WHICH BIOLOGICAL COLLECTIONS WERE MADE

LIST OF STATIONS WHERE BE MULTIPLE PLANKTON SAMPLER WAS USED

SAMPLE OR STATION NO.	DATE	LOCATION	REGION	SAMPLING DEPTH (M)	TIME (LOCAL)
GILLISS-1-A (shallow)	11 Nov 65	25°45'N, 72°12'W	S.W. Sargasso Sea (Area Bravo)	100-0	1244-1255
2A	11 Nov 65	25°44'N, 72°19'W	S.W. Sargasso Sea (Area Bravo)	65-0	2042-2143
3A	12 Nov 65	25°44'N, 72°15'W	S.W. Sargasso Sea (Area Bravo)	350-0	0945-1137
4A	12-13 Nov 65	25°42'N, 72°17'W	S.W. Sargasso Sea (Area Bravo)	45-0	2215-0015
1B	18-19 Nov 65	25°45'N, 72°47'W	S.W. Sargasso Sea (Area Bravo)	25-0	2302-0009
1BC	20 Nov 65	25°36'N, 72°38'W	S.W. Sargasso Sea (Area Bravo)	1000-0	1136-1430
1C	20 Nov 65	25°30'N, 72°30'W	S.W. Sargasso Sea (Area Bravo)	35-0	1925-2038
1D (deep)	22 Nov 65	25°15'N, 72°15'W	S.W. Sargasso Sea (Area Bravo)	1000-800	1054-1154
1-D (mid)	22 Nov 65	25°15'N, 72°15'W	S.W. Sargasso Sea (Area Bravo)	800-600	1154-1302
1-D (shallow)	22 Nov 65	25°15'N, 72°15'W	S.W. Sargasso Sea (Area Bravo)	600-0	1302-1436
2-D	23 Nov 65	25°11'N, 72°15'W	S.W. Sargasso Sea (Area Bravo)	110-0	1344-1505
3-D	23 Nov 65	25°10.5'N, 72°13'W	S.W. Sargasso Sea (Area Bravo)	60-0	2140-2302
1-E	24 Nov 65	25°15'N, 72°45'W	S.W. Sargasso Sea (Area Bravo)	750-0	0946-1338
2-E	25 Nov 65	25°15'N, 72°45'W	S.W. Sargasso Sea (Area Bravo)	60-0	0904-1008
SANDS 3A	22 Mar 66	25°26'N, 72°25.5'W	S.W. Sargasso Sea (Area Bravo)	91-0	2048-2130
4A	22 Mar 66	25°27'N, 72°27'W	S.W. Sargasso Sea (Area Bravo)	46-0	2135-2202
6A	23 Mar 66	25°29.9'N, 72°30.8'W	S.W. Sargasso Sea (Area Bravo)	102-0	1533-1608
7A	23 Mar 66	25°31'N, 72°27'W	S.W. Sargasso Sea (Area Bravo)	122-0	2115-2140
8A	23 Mar 66	25°30.5'N, 72°24.5'W	S.W. Sargasso Sea (Area Bravo)	138-0	2150-2215
9A	23 Mar 66	25°31'N, 72°22.5'W	S.W. Sargasso Sea (Area Bravo)	38-0	2228-2251
10A	24 Mar 66	25°24'N, 72°36'W	S.W. Sargasso Sea (Area Bravo)	49-0	0915-0955
11A	24 Mar 66	25°28'N, 72°39.8'W	S.W. Sargasso Sea (Area Bravo)	86-0	1013-1100
12B	25 Mar 66	25°15'N, 72°45'W	S.W. Sargasso Sea (Area Bravo)	79-0	2025-2100
13B	25 Mar 66	25°15'N, 72°45'W	S.W. Sargasso Sea (Area Bravo)	96-0	2117-2155
14B	25 Mar 66	25°15'N, 72°45'W	S.W. Sargasso Sea (Area Bravo)	32-0	2210-2250
LYNCH 2 #4	15 Jun 66	31°30'N, 75°00'W	Western Atlantic	100-0	2015-2130
Lima 3	22 Jun 66	24°41.5'N, 85°25'W	Gulf of Mexico	90-0	2127-2215
Lima 4	23 Jun 66	24°38'N, 85°31'W	Gulf of Mexico	90-0	0010-0055
Lima 2 #2	23 Jun 66	24°10'N, 85°10'W	Gulf of Mexico	90-0	2127-2210
Lima 2 #3	24 Jun 66	24°10'N, 85°05'W	Gulf of Mexico	90-0	0012-0100

LIST OF NET HAULS TAKEN BY USNS SANDS USING SIX FOOT ISAACS-KIDD MIDWATER TRAWL WITH DDPS

STATION	DATE	LOCATION	REGION	SAMPLING DEPTH (m)	TIME OF SAMPLING (LOCAL)
1-T1-A-D	23 March 1967	25°08'N, 89°08'W	Gulf of Mexico	418 - 0	2015 - 2218
1-T2-A	24 March 1967	25°07'N, 89°04.3'W	Gulf of Mexico	141 - 150	0128 - 0158
1-T2-B	24 March 1967	25°07'N, 89°04.3'W	Gulf of Mexico	150 - 85	0158 - 0208
1-T2-C	24 March 1967	25°07'N, 89°04.3'W	Gulf of Mexico	85 - 79	0208 - 0238
1-T2-D	24 March 1967	25°07'N, 89°04.3'W	Gulf of Mexico	79 - 0	0238 - 0246
2-T1-A	24 March 1967	25°36'N, 88°01'W	Gulf of Mexico	228 - 255	1150 - 1320
2-T1-B	24 March 1967	25°36'N, 88°01'W	Gulf of Mexico	255 - 80	1320 - 1339
2-T1-C	24 March 1967	25°36'N, 88°01'W	Gulf of Mexico	80 - 74	1339 - 1409
2-T1-D	24 March 1967	25°36'N, 88°01'W	Gulf of Mexico	74 - 0	1409 - 1413
3-T1-A	25 March 1967	25°48'N, 87°05'W	Gulf of Mexico	152 - 167	0050 - 0120
3-T1-B	25 March 1967	25°48'N, 87°05'W	Gulf of Mexico	167 - 80	0120 - 0130
3-T1-C	25 March 1967	25°48'N, 87°05'W	Gulf of Mexico	80 - 84	0130 - 0200
3-T1-D	25 March 1967	25°48'N, 87°05'W	Gulf of Mexico	84 - 0	0200 - 0209
4-T1-A	25 March 1967	25°56'N, 86°58'W	Gulf of Mexico	309 - 328	1055 - 1125
4-T1-B	25 March 1967	25°56'N, 86°58'W	Gulf of Mexico	313 - 91	1125 - 1150
4-T1-C	25 March 1967	25°56'N, 86°58'W	Gulf of Mexico	91 - 82	1150 - 1220
4-T1-D	25 March 1967	25°56'N, 86°58'W	Gulf of Mexico	82 - 0	1220 - 1241
5-T1-A	26 March 1967	26°16'N, 85°03'W	Gulf of Mexico	138 - 152	0233 - 0303
5-T1-B	26 March 1967	26°16'N, 85°03'W	Gulf of Mexico	144 - 88	0303 - 0340
5-T1-C&D	26 March 1967	26°16'N, 85°03'W	Gulf of Mexico	88 - 0	0340 - 0420
5-T2-A	26 March 1967	26°13'N, 85°08'W	Gulf of Mexico	145 - 119	0605 - 0635
5-T2-B	26 March 1967	26°13'N, 85°08'W	Gulf of Mexico	125 - 69	0635 - 0700
5-T2-C&D	26 March 1967	26°13'N, 85°08'W	Gulf of Mexico	74 - 0	0700 - 0740
7-T1-A	28 March 1967	23°58.5'N, 85°30'W	Gulf of Mexico	106	0106 - 0206
7-T1-B	28 March 1967	23°58.5'N, 85°30'W	Gulf of Mexico	106 - 50	0206 - 0220
7-T1-C	28 March 1967	23°58.5'N, 85°30'W	Gulf of Mexico	50	0220 - 0250
7-T1-D	28 March 1967	23°58.5'N, 85°30'W	Gulf of Mexico	50 - 0	0250 - 0256
7-T2-A	28 March 1967	24°03'N, 85°32.2'W	Gulf of Mexico	374 - 360	1120 - 1220
7-T2-B	28 March 1967	24°03'N, 85°32.2'W	Gulf of Mexico	360 - 317	1220 - 1233
7-T2-C	28 March 1967	24°03'N, 85°32.2'W	Gulf of Mexico	317 - 309	1233 - 1333
7-T2-D	28 March 1967	24°03'N, 85°32.2'W	Gulf of Mexico	309 - 0	1333 - 1406
7-T3-A-D	29 March 1967	23°58'N, 85°37'W	Gulf of Mexico	125 - 0	0524 - 0750
7-T4-A	29 March 1967	24°01'N, 85°20'W	Gulf of Mexico	345 - 372	1100 - 1200
7-T4-B	29 March 1967	24°01'N, 85°20'W	Gulf of Mexico	372 - 307	1200 - 1226
7-T4-C	29 March 1967	24°01'N, 85°20'W	Gulf of Mexico	307 - 317	1226 - 1328
7-T4-D	29 March 1967	24°01'N, 85°20'W	Gulf of Mexico	308 - 0	1328 - 1400
8-T1-A	3 April 1967	31°34'N, 75°26'W	Western Atlantic	100 - 103	0400 - 0455
8-T1-B	3 April 1967	31°34'N, 75°26'W	Western Atlantic	103	0455 - 0550
8-T1-C&D	3 April 1967	31°34'N, 75°26'W	Western Atlantic	105 - 0	0500 - 0737
8-T2	3 April 1967	31°34.5'N, 75°24.5'W	Western Atlantic	475 - 0	1100 - 1311
8-T3-A	3 April 1967	31°30'N, 75°20'W	Western Atlantic	88	1724 - 1754
8-T3-B	3 April 1967	31°30'N, 75°20'W	Western Atlantic	86 - 88	1754 - 1830
8-T3-C&D	3 April 1967	31°30'N, 75°20'W	Western Atlantic	86 - 0	1830 - 1937
9-T1-A	5-6 April 1967	35°03'N, 74°41'W	Gulf Stream	363 - 307	2330 - 0048
9-T1-B	5-6 April 1967	35°03'N, 74°41'W	Gulf Stream	307 - 228	0048 - 0100
9-T1-C&D	5-6 April 1967	35°03'N, 74°41'W	Gulf Stream	228 - 0	0100 - 0235
9-T2-A	6 April 1967	35°07'N, 74°40'W	Gulf Stream	123 - 112	0450 - 0520
9-T2-B	6 April 1967	35°07'N, 74°40'W	Gulf Stream	118 - 132	0520 - 0550
9-T2-C	6 April 1967	35°07'N, 74°40'W	Gulf Stream	122 - 132	0550 - 0620
9-T2-D	6 April 1967	35°07'N, 74°40'W	Gulf Stream	132 - 0	0620 - 0700

LIST OF DIPNET STATIONS

STATION	DATE	LOCATION	REGION	TIME (LOCAL)
1 - D1	23-24 March 1967	25°06'N, 89°08.8'W	Gulf of Mexico	2230 - 0100
3 - D1	25 March 1967	25°48'N, 87°05'W	Gulf of Mexico	0500
7 - D1	28 March 1967	23°58.5'N, 85°30'W	Gulf of Mexico	0400 - 0600
7 - D2	28-29 March 1967	23°55'N, 85°27.5'W	Gulf of Mexico	1530 - 0100
8 - D1	3 April 1967	31°30'N, 75°30'W	Western Atlantic	2100 - 2300
Bravo	November 1965	25°30'N, 72°30'W (Center coordinates for one-degree square)	SW Sargasso Sea (Area Bravo)	Various

APPENDIX B

CHECK LIST OF THE SPECIES OF FISHES COLLECTED

APPENDIX B

LIST OF FISHES COLLECTED

Following the species name are the collection numbers and, in parentheses, the number of specimens and their size range (standard lengths).

GULF OF MEXICO

Order Salmoniformes

Gonostomatidae

Bonapartia pedaliota, Goode and Bean, 1-T1-A to D (1,23mm); 7-T2-C (3,25-30.5mm); 7-T2-D(1,32mm); 7-T4-B(1,30mm).
Cyclothone pseudopallida, Mukhacheva. 1-T1-A to D (2,25 & 28.5mm).
Gonostoma atlanticum, Norman. 3-T1-B(1,26mm).
Gonostoma elongatum, Günther. 5-T1-B(1,113mm); Lima2#3(1,32mm).
Maurolicus mulleri, (Gmelin). 1-T1-A to D(1,16.5mm).
Pollichthys mauli, (Poll). 3-T1-D(1,38.5mm); 7-T1-A(2,30&37mm); 7-T1-D(1,32mm); 7-T2-A(1,35mm); 7-T3(2,17 & 19mm).
Valencienellus tripunctulatus, (Esmark). 1-T1-A to D(1,26.5mm).
Vinciguerria attenuata, (Cocco). 1-T1-A to D(1,24mm).
Vinciguerria nimbaria, (Jordan and Williams). 1-T2-D(1,18mm); 3-T1-B (1,18mm); 5-T1-B(1,29.5mm); 7-T3(1,17mm).
Vinciguerria poweriae, (Cocco). 1-T2-A(3,30-33.5mm); 5-T1-A(3,27-32mm); 5-T1-B(6,21.5-31mm)(1,17.5mm larvae?).

Sternoptychidae

Argyropelecus aculeatus, Cuvier and Valenciennes. 1-T1-A to D (4,16-46mm); 5-T1-A(3,17-25.5mm); 1-T2-A(3,20.5-22.5mm); 1-T2-D(1,12mm); 5-T1-B(2,10.5&18.5mm).
Argyropelecus hemigymnus, Cocco. 1-T1-A to D(1,16mm).
Polyipnus asteroides, Schultz. 1-T1-A to D(1,22mm).

Melanostomiatidae

Bathophilus longipinnis, (Pappenheim). 2-T1-D(1,ca. 25mm).
Echiostoma barbatum, Lowe. 7-T2-D(1,45mm).

Chauliodontidae

Chauliodus sloani, Bloch and Schneider. 7-T1-A(1,68mm); 7-T3(1,25mm).

Stomiatidae

Stomias affinis, Günther. Lima 2#2(1,53mm).

Idiacanthidae

Idiacanthus fasciola, Peters. 1-T2-D(1,47mm).

Paralepididae

Paralepis coregonoides barracudina, Fowler and Phillips. 7-T4-D(1,11mm).

Scopelarchidae

Scopelarchus sagax, Rofen. 2-T1-A(1,28mm).
Scopelarchus sp. 7-T4-B(1,22mm).

Myctophidae

Hygophum benoiti, (Cocco). 1-T1-A to D(1,39mm); 5-T1-A(1,40mm).
Hygophum hygomi, (Lütken). 1-T1-A to D(1,24mm); 1-T2-C(1,25mm); 5-T1-B(2,15.5&30mm); 7-T3(1,42mm).
Hygophum macrochir, (Günther). 5-T1-C & D(1,14.5mm).
Hygophum taaningi, Becker. 3-T1-A(3,22-30mm); 7-T1-C(2,33.5&35mm); 7-T1-D(1,28mm).
Benthosema suborbitale, (Gilbert). 1-T1-A to D(14,12-26mm); 1-T2-D (4,16-26mm); 5-T1-B(1,25mm); 5-T1-C&D(2,15.5&24mm); 7-T3(1,ca. 14mm); Lima 2 #2(2,11&12.5mm); Lima 2 #3(1,11.5mm); Lima 3(3,12.5-25mm); Lima 4(2,11&24.5mm).
Gonichthys cocco, (Cocco). Lima 2 #2(1,28.5mm).
Diogenichthys atlanticus, Tåning. 1-T1-A to D(5,14-19.5mm); 1-T2-C (3,14.5-21mm); 1-T2-D(3,15-19.5mm); 2-T1-D(1,13.5mm); 5-T1-C&D (2,13.5&21mm); 7-T1-A(1,16mm); Lima 2 #2(1,11.5mm); Lima 4(1,12.5mm).
Symbolophorus rufinus, (Tåning). 7-D2(1,71.5mm).
Myctophum affine, (Lütken). 1-D1(2,41&55mm); 7-D2(9,49-56mm); Lima 2 #2(2,15.5&16.5mm); Lima 2# 3(1,15.5mm); Lima 4(1,15.5mm).
Myctophum asperum, Richardson. 7-T1-B(1,22mm).
Myctophum nitidulum, Garman. 1-D1(1,59mm); 3-D1(1,19mm); 5-T1-A (1,29mm); 7-D2(6,22.5-69mm).
Diaphus brachycephalus, Tåning. 3-T1-B(1,28mm); 7-T1-C(1,12mm); 7-T3 (1,ca. 14mm); Lima 3(1,12mm).
Diaphus dumerili, (Bleeker). 1-T1-A to D(9,13.5-19mm); 1-T2-C(3,14-17.5 mm); 1-T2-D(2,13&22.5mm); 4-T1-D(1,11mm); 5-T1-C&D(1,46.5mm); 7-T1-A (1,23mm); 7-T1-B(1,17mm); 7-T1-D(2,17&17.5mm); 7-T3(1,20mm); Lima #3 (1,17mm).
Diaphus elucens, (Brauer). 1-T1-A to D(1,55mm); 1-T2-C(1,44.5mm); 3-T1-C(1,12mm); 5-T1-C&D(2,52&57.5mm); Lima 2 #2(1,9.5mm).
Diaphus lucidus, (Goode and Bean). 5-T1-B(1,24.5mm).
Diaphus lutkeni, (Brauer). 1-T1-A to D(1,13.5mm); 5-T1-A(1,39mm); 5-T1-C&D(1,26mm); 5-T2-B(1,21.5mm).

Myctophidae (Continued)

Diaphus mollis, Taning. 3-T1-A(1,37mm); 5-T1-B(6,29-39mm); 5-T1-C&D(1,16mm); 7-T1-A(1,10.5mm); 7-T3(1,13mm); Lima #3 (1,9mm).

Diaphus problematicus, Parr. 1-T1-A to D(1,14mm).

Diaphus rafinesquei, (Cocco). 1-T1-A to D(2,13&19mm); 5-T1-B(1,18mm).

Diaphus splendidus, (Brauer). 7-T1-A(28,13-27mm); 7-T1-D(1,15.5mm); Lima 2#3(3,12-18mm); Lima 3(5,14.5-26mm); Lima 4(2,12.5&22mm).

Notolychnus valdiviae, Brauer. 1-T1-A to D(14,14.5-19.5mm); 1-T2-A (1,18.5mm); 1-T2-C(5,17-21mm); 1-T2-D(25,13-20mm); 3-T1-A(1,18mm); 3-T1-B(1,17mm); 3-T1-D(1,15mm); 5-T1-B(8,13-19mm); 7-T1-B(3,15-19mm); 7-T1-C(3,16-18mm); 7-T1-D(2,15.5&18mm); 7-T2-D(2,15.5&16mm); 7-T3 (3,17-19mm); Lima 2#3(3,10.5-16mm); Lima 3(9,10.5-19.5mm); Lima 4 (2,10.5&14mm).

Lampanyctus alatus, Goode and Bean. 5-T1-A(1,46mm); Lima 3(4,17-22.5 mm); Lima 4(3,16-28.5mm).

Lampanyctus sp. 1-T2-A(1,44.5mm).

Lepidophanes gaussi, (Brauer). 7-T1-B(1,ca. 15mm); 7-T3(1,15.5mm). Lima 2#3(1,15.5mm).

Lepidophanes guntheri, (Goode and Bean). 1-T1-A to D(8,17-54mm); 1-T2-C(16,19-58mm); 1-T2-D(2,36&55mm); 3-T1-B(1,39mm); 3-T1-C (1,21.5mm); 3-T1-D(2,23&25.5mm); 5-T1-B(2,38&41mm); 5-T2-C&D (1,ca. 20mm); 7-T1-A(23,16-43.5mm); 5-T1-B(1,22mm); 7-T1-C(2,22.5& ca. 48.5mm); 7-T1-D(1,33mm); 7-T2-C(1,ca. 20mm); 7-T3(21,16-46mm); Lima 2#2(2,14.5&43mm); Lima 2#3(2,18&20mm); Lima 3(1,21.5mm).

Lepidophanes pyrsobolus, (Alcock). 3-T1-A(1,25.5mm); 3-T1-B(2,16&18mm); 5-T1-B(2,18&23mm).

Ceratoscopelus warmingi, (Lütken). 1-T1-A to D(5,21-46mm); 1-T2-D (5,19.5-32.5mm); 3-T1-C(1,21.5mm); 5-T1-A(1,18.5mm); 5-T1-B(2,50.5& 63mm); 5-T1-C&D(1,51.5mm); 7-T1-A(1,54.5mm); Lima 2#3(4,19.5-24.5mm); Lima 3(5,19-30mm).

Notoscopelus caudispinosus, (Johnson). 1-T2-C(1,35mm); 1-T2-D(1,55mm); 4-T1-D(1,12mm); 5-T1-B(1,18.5mm); 7-T1-A(1,19mm).

Notoscopelus resplendens, (Richardson). 1-T1-A to D(10,25-40mm); 1-T2-A (2,20.5&23.5mm) 1-T2-C(4,26-35mm); 1-T2-D(1,21mm); 5-T1-A(2,15.5& 17.5mm); 5-T1-B(1,28mm)(3,12-17mm post larvae); 5-T1-C&D(3,16-31.5mm); 5-T2-A(1,24mm); 7-T1-A(2,25.0&25.5).

Order Lophiiformes

Antennariidae

Antennarius multiocellatus(?), (Cuvier and Valenciennes). 5-T1-A(1,8.5mm); 5-T1-B(1,7mm).

Antennariidae (Continued)

Antennarius radiosus, Garman. 1-T1-A to D(1,13.5mm); 5-T2-A (1,18mm); 5-T2-C&D(1,13mm).

Order Gadiformes

Bregmacerotidae

Bregmaceros atlanticus, Goode and Bean. 2-T1-C(1,12mm); 5-T1-B (1,18.5mm).

Order Beryciformes

Melamphaidae

Melamphaes simus, Ebeling. T-T1-A to D(4,18.5-25.5mm); 1-T2-A (1,19mm); 5-T1-B(1,15mm).

Polymixiidae

Polymixia sp. 1-T2-A(1,8mm).

Diretmidae

Diretmus argenteus, Johnson. 7-T4-A(1,10.5mm).

Order Lampridiformes

Trachipteridae

Trachipterus sp. 1-T1-A to D(1,25mm).

Order Perciformes

Priacanthidae

Priacanthus arenatus, Cuvier and Valenciennes. 4-T1-D(2,10&12mm).

Bramidae

Brama sp. 1-T1-A to D(1,50mm).
Pterycombus brama, Fries. 7-T1-A(1,10mm).

Caristiidae

Caristius japonicus, Gill and Smith. 5-T2-A(1,19mm).

Acanthuridae

Acanthurus sp. 2-T1-C(1,9mm); 4-T1-D(5,6-9mm); 7-T1-A(3,7-9); 7-T1-C (2,7.5&8mm); 7-T1-D(7,7-11mm); 7-T2-B(1,8.5mm); 7-T3(11,7.5-16mm).

Gempylidae

Nealotus sp. 1-T1-A to D(2,17&27mm).

Trichiuridae

Diplospinus multistriatus, Maul. 1-T1-A to D(1,19.5mm); 2-T1-C (1,22.5mm); 5-T1-B(1,103mm); 7-T2-D(1,19mm).
Benthodesmus simonyi, Steindachner. 3-T1-B(1,18mm).

Tetragonuridae

Tetragonurus atlanticus, Lowe. 1-T1-A to D(1,18mm).

Order Tetraodontiformes

Balistidae

Stephanolepis hispidus (?), (Linnaeus). 3-T1-D(1,9.5mm); 4-T1-C (2,9-17.5mm).
Stephanolepis setifer (?), Bennett. 4-T1-B(1,9mm).

AREA BRAVO

Order Anguilliformes

Nemichthyidae

Nemichthys scolopaceus, Richardson. 1-B(2,282&315mm).

Order Salmoniformes

Opisthoproctidae

Rhyncohyalus natalensis, (Gilchrist and von Bonde). 1-E(1,12mm).

Gonostomatidae

Cyclothone braueri, Jesperson and Tåning. 1-BC(98,11-22mm); 1-C(5,13mm); 1-D(shallow)(1,16mm); 1-D(deep)(75,11-23mm); 2-D(1,11mm); 1-E(64, 11-23mm).
Cyclothone microdon, Günther. 1-BC(6,7-14mm); 1-D(deep)(4,11-12mm).
Cyclothone pallida, Brauer. 1-BC(25,11-27mm); 1-D(middle)(1,45mm); 1-E(5,12-16mm).
Cyclothone pseudopallida, Mukhacheva. 1-BC(1,23mm); 1-D(middle) (15,15-30mm); 1-E(1,18mm).
Gonostoma elongatum, Günther. 1-A(shallow)(1,4.5mm); 13-B(4,10-23mm).
Pollichthys mauli, Poll. 2-A(1,17mm); 1-C(2,18&24mm); 3-A(1,41mm); 4-A(2,21&32mm); 13-B(1,18mm); 14-B(1,38mm).
Vinciguerria nimbaria, Jordan and Williams. 1-BC(1,14mm).

Sternoptychidae

Argyropelecus aculeatus, Cuvier and Valenciennes. 1-D(deep)(1,ca. 7mm).
Argyropelecus hemigymnus, Cocco. 1-BC(2,10&11mm); 1-E(1,16mm); 1-D(shallow)(1,8mm); 1-D(deep)(2,7mm).

Malacosteidae

Photostomias guernei, Collett. 1-D(deep)(1,31mm); 3-D(4,29-33mm).

Chauliodontidae

Chauliodus danae, Regan and Trewavas. 1-D(deep)(2,23&89mm); 3-D (1,16mm); 13-B(1,19mm).

Stomiatidae

Stomias affinis, Günther. 14-B(1,50mm).
Stomias brevibarbatus, Ege. 1-BC(1,33mm).

Idiacanthidae

Idiacanthus fasciola, Peters. 1-BC(1,81mm); 1-D(deep)(2,62&64mm).

Paralepididae

Lestidiops affinis, Ege. 1-BC(1,25mm); 1-C(1,24mm); 3-A(2,32mm); 10-A(1,20mm); 11-A(1,30mm); 13-B(4,19-40mm); 14-B(2,10&24mm).
Macroparalepis affine americana, Rofen. 2-A(1,22mm); 4-A(2,27mm).
Macroparalepis breve, Ege. 8-A(1,27mm).
Paralepis elongata, Brauer. 1-D(deep)(1,41mm).

Evermannellidae

Coccorella atrata, (Alcock). 2-A(2,6&10mm); 8-A(1,17mm).

Scopelarchidae

Scopelarchus beebei, Rofen. 13-B(1,18mm).
Scopelarchus candelops, Rofen. 6-A(1,8.5mm); 13-B(1,9mm).

Myctophidae

Hygophum benoiti, Cocco. 1-BC(1,14.5mm).
Hygophum hygomi, (Lütken). 4-A(1,25mm); 13-B(2,15&16mm).
Diogenichthys atlanticus, Tåning. 1-BC(1,12mm); 1-D(deep)(1,14mm).
Centrobranchus nigroocellatus, Günther. 4-A(1,13mm); 13-B(2,21&25mm).
Gonichthys cocco, (Cocco). 13-B(1,18mm).
Myctophum selenops, Tåning. 1-E(1,15.5mm).
Diaphus effulgens, (Goode and Bean). 1-BC(1,12mm); 1-D(deep)(1,11mm).
Diaphus holti, (?) Tåning. 13-B(1,10mm).

Myctophidae (Continued)

Notolychnus valdiviae, Brauer. 2-A(2,10&11mm); 1-BC(14,11-18mm); 1-C(1,10mm); 1-D(deep)(2,10&14mm); 3-D(3,12-16mm); 1-E(1,9mm); 4-A(1,15mm); 7-A(4,15-19mm); 14-B(1,17mm).

Lampanyctus alatus, Goode and Bean. 7-A(1,47mm).

Lampanyctus cuprarius, Tåning. 1-BC(2,22&23mm); 8-A(1,32.5mm).

Lampanyctus photonotus, Parr. 1-B(1,23mm); 12-B(1,32mm).

Lampanyctus pusillus, (Johnson). 3-D(1,27mm).

Lepidophanes gaussi, (Brauer). 1-BC(2,16mm); 1-C(6,16-28mm); 1-D(deep) (3,16mm); 3-D(2,15mm); 4-A(6,15-16mm); 7-A(4,15-37mm); 8-A(1,31mm); 14-B(1,16mm).

Lepidophanes pyrsobolus, (Alcock). 1-BC(2,14&16mm); 1-D(deep)(1,18mm).

Lepidophanes supralateralis, Parr. 3-D(1,13mm).

Ceratoscopelus warmingi, (Lütken). 3-D(3,17-18mm); 7-A(1,17mm); 14-B (2,18&22mm).

Order Lophiiformes

Gigantactinidae

Gigantactis sp. (type A in Regan and Trewavas, 1932). 2-D(1,4.5mm).

Ceratiidae

Cryptosparas couseii (?), Gill. 2-E(1,4.5mm).

Order Gadiformes

Bregmacerotidae

Bregmaceros atlanticus, Goode and Bean. 1-BC(1,7mm); 7-A(1,11mm); 13-B(2,7&11mm).

Order Beryciformes

Melamphaidae

Melamphaes pumilus, Ebeling. 3-D(2,10&11.5mm); 7-A(1,15mm); 13-B (2,11&12mm).

Scopelogadus mizolepis mizolepis, (Günther). 1-BC(1,13mm).

Anoplogasteridae

Anoplogaster cornutus, Cuvier and Valenciennes. 2-D(1,5mm).

Order Perciformes

Trichiuridae

Diplospinus multistriatus, Maul. 8-A(1,54mm).

OTHER WESTERN ATLANTIC STATIONS

Order Salmoniformes

Gonostomatidae

Cyclothone braueri, Jesperson and Tåning. 8-T2(186,15-25.5mm).
Gonostoma elongatum, Günther. 8-T1-B(1,28.5mm); 9-T2-A(1,27.5mm); 9-T2-D(1,16.5mm).
Pollichthys mauli, Poll. 8-T1-B(1,20mm); 8-T1-C(1,21mm); 8-T3-C&D (3,16-27mm); 9-T2-A(2,16&18mm); 9-T2-B(1,21.5mm); 9-T2-C(2,21.5& 25.5mm); 9-T2-D(1,20mm).
Valenciennellus tripunctulatus, (Esmark). 8-T2(1,21mm).
Vinciguerria nimbaria, (Jordan and Williams). 8-T1-A(1,17mm); 8-T3-C&D (1,15mm); 9-T1-C&D(1,17mm).
Vinciguerria poweriae, (Cocco). 8-T1-A(3,ca. 14mm).

Sternoptychidae

Argyropelecus aculeatus, Cuvier and Valenciennes. 8-T2(1,11.5mm).
Argyropelecus hemigymnus, Cocco. 8-T2(5,11.5-22.5mm); 9-T1-C&D (1,21mm).
Sternoptyx diaphana, Hermann. 8-T3-A(1,7.5mm).

Chauliodontidae

Chauliodus danae, Regan and Trewavas. 8-T1-A(1,34mm); 8-T1-B (2,19&21.5mm); 8-T2(1,34mm).

Stomiatidae

Stomias brevibarbatus, Ege. 8-T1-A(1,69.6mm).

Idiacanthidae

Idiacanthus fasciola, Peters. 8-T1-C(1,177mm).

Paralepididae

Paralepis coregonoides barracudina, Fowler and Phillips. 8-T1-B(1,17mm).
Lestidiops jayakari, (Boulenger). 8-T1-B(1,35mm).
Lestidiops affinis, Ege. 8-T3-C&D(2,38mm).
Stemnosudis intermedia, Ege. 8-T3-C&D(1,37mm); 9-T2-D(1,25mm).

Evermannellidae

Coccorella atrata, (Alcock). 8-T1-C(1,35mm).

Scopelarchidae

Scopelarchus sagax, Rofen. 9-T1-C&D(1,23mm).

Scopelosauridae

Scopelosaurus smithii (?), Bean. 8-T1-A(3,33-43mm).

Myctophidae

Hygophum benoiti, Cocco. 8-T1-C(1,38mm).
Hygophum hygomi, (Lütken). 8-T1-B(6,20.5-27mm); 8-T3-C&D (7,19-28.5mm); 9-T1-C&D(1,18.5mm).
Gonichthys cocco, Cocco. 8-T1-C(1,33.5mm).
Gonichthys sp. 8-T1-B(1,22mm).
Diogenichthys atlanticus, Tåning. 8-T1-B(4,14-18mm); 8-T3-C&D (17,13.5-18mm); 2#4(3,18-20.5mm).
Myctophum nitidulum, Garman. 8-D1(7,42.5-67mm).
Myctophum selenops, Tåning. 9-T1-C&D(1,15mm).
Lobianchia dolfleini, Zugmayer. 8-T1-A(4,10-27mm); 8-T2(5,11-19.5mm); 8-T3-C&D(4,10.5-13mm); 2#4(7,17-22mm).
Lobianchia gemellari, (Cocco). 8-T1-A(2,13&14mm); 8-T1-B(2,11&14.5 mm); 8-T2(10,13-14.5mm); 8-T3-C&D(1,12.5mm).
Diaphus dumerili, (Bleeker). 9-T1-C&D(1,13mm); 9-T2-A(1,20.5mm).
Diaphus effulgens, (Goode and Bean). 8-T1-A(1,25mm).
Diaphus mollis, Tåning. 8-T1-A(2,29&37.5mm); 8-T1-B(3,33.5-38.5mm); 8-T1-C(4,31-41.5mm); 8-T3-C&D(7,35-41.5mm); 9-T2-A(1,21mm).
Diaphus rafinesquei, (Cocco). 8-T3-C&D(1,21.5mm).
Diaphus splendidus, (Brauer). 8-T1-B(1,57mm).
Diaphus sp. 7-T1-D(1,17mm); 7-T3(8,13-14mm); 8-T1-C&D(1,18mm).
Notolychnus valdiviae, Brauer. 8-T1-A(9,16.5-18mm); 8-T1-B(1,20mm); 8-T1-C(1,15.5mm); 8-T2(53,15-19.5mm); 8-T3-C&D(2,18&19mm).
Lampanyctus ater, Tåning. 9-T1-C&D(1,ca. 36mm).
Lampanyctus photonotus, Parr. 8-T1-A(1,55mm).
Lampanyctus pusillus, (Johnson). 8-T1-A(2,19&28.5mm); 8-T1-B(2,28& 30.5mm); 8-T3-C&D(2,15&15.5mm).
Lepidophanes gaussi, (Brauer). 8-T1-B(1,34.5mm); 8-T3-C&D(1,16mm); 2#4(1,15mm).
Lepidophanes guntheri, (Goode and Bean). 8-T1-A(2,30&36mm); 9-T1-C&D(10,19-55mm); 9-T2-A(1,30mm).
Lepidophanes pyrsobolus, (Alcock). 8-T1-A(6,19-30mm); 8-T1-B(10, 20.5-32mm); 8-T1-C(8,20-26mm); 8-T3-C&D(17,19.5-31mm).

Myctophidae (Continued)

Ceratoscopelus warmingi, (Lütken). 8-T1-A(1,61mm); 8-T1-C(1,40.5mm); 8-T3-C&D(11,33-59mm); 9-T1-C&D(1,20mm).

Notoscopelus caudispinosus, (Johnson). 8-T1-B(3,21.5-54mm); 8-T1-C (1,48mm); 8-T3-C&D(2,34&50mm); 9-T1-C&D(1,19.5mm).

Notoscopelus resplendens, (Richardson). 8-T1-A(3,10.5-68mm); 8-T1-B (6,12-16mm); 8-T3-B(1,13mm); 8-T3-C&D(2,58&62mm).

Order Lophiiformes

Antennariidae

Antennarius multiocellatus (?), (Cuvier and Valenciennes). 8-T1-A (1,5mm); 8-T1-B(5,4.5-8mm); 8-T1-C(6,4.5-9.5mm); 8-T2(1,9.5mm); 8-T3-B(1,5.5mm); 9-T1-B(1,6mm); 9-T2-A(1,4.5mm); 9-T2-B(1,6mm).

Histrio histrio, (Linnaeus). 8-T1-B(1,9mm); 8-T1-C(1,15.5mm); 8-D1(1,11mm).

Order Gadiformes

Bregmacerotidae

Bregmaceros atlanticus, Goode and Bean. 8-T1-A(3,19-32mm).

Order Beryciformes

Melamphaidae

Melamphaes pumilus (?), Ebeling. 8-T1-A(2,ca. 12mm).

Polymixiidae

Polymixia sp. 8-T1-C(1,13mm); 9-T1-C&D(2,11&13mm).

Anoplogasteridae

Anoplogaster cornutus, Cuvier and Valenciennes. 9-T2-C(1,6mm).

Order Perciformes

Bramidae

Pterycombus brama, Fries. 9-T1-C&D(1,8mm).

Acanthuridae

Acanthurus sp. 9-T2-C(1,6mm).

Gempylidae

Nealotus sp. 8-T1-A(1,30mm); 8-T3-B(2,14&47mm); 8-T3-C&D(3,10-27.5mm).

Nesiarchus nasutus, Johnson. 9-T1-A(3,245-258mm).

Trichiuridae

Diplospinus multistriatus, Maul. 8-T1-A(2,18.5&30mm); 8-T1-B(1,41.5 mm); 8-T1-C(1,85.5mm); 8-T3-A(1,19.5mm); 8-T2-B(3,18-22mm); 8-T3-C&D(3,19-153mm); 9-T2-B(1,24.5mm); 2 #4(1,27mm).

Benthodesmus simonyi, Steindachner. 8-T1-B(1,25.5mm); 9-T1-C&D (1,48mm).

Order Tetraodontiformes

Molidae

Mola mola, (Linnaeus). 8-T1-A(3,3-5.5mm); 9-T2-D(1,7mm).

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Appendix A presents the station data and Appendix B presents a check list of the species of fishes collected.

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